CATCH WATER WHERE IT FALLS

TOOLKIT ON URBAN RAINWATER HARVESTING

To the jal yodhas of urban India who made this book possible

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Centre for Science and Environment

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Preface

Water will determine if India becomes wealthy or remains poor. But the management of water is not simply about building more dams or pipelines to take the water to our cities and pipelines to flush the waste from our homes. The management of water is about building the relationship of society with its water, so that we can understand the value of each raindrop and understand that unless we are prudent, indeed frugal, with our use of this precious resource, there will never be enough water for all.

Water management is then about society and its ability to create technologies to maximise the use of water and more importantly, technologies to share water with all. It is for this reason that we must re-learn the water wisdom of the past. In the late 1990s, CSE published its book *Dying Wisdom: The Rise, Fall and Potential of India's Traditional Water Harvesting Systems,* which documented the extraordinary wealth and ingenuity of its people living across different ecological systems to manage water. The systems ranged from ways of harvesting glacier water in the cold deserts to delivering water with precision over long distances through bamboo drip irrigation systems in the northeastern hills of India.

The *kundi* of the hot desert of India incorporates the simplest of technologies for powerful impact. Rain is harvested on an artificially created piece of land, which is sloped towards a well to store precious water. The water maths is equally simple; As little as 100 mm of rainwater harvested on 1 ha of land will collect 1 million litres of water in this structure. On the other hand, in the other regions of the country, people harvested floodwaters.

In other words, people had learnt to live, with the excesses of water, and with its scarcity. They all worked on the principle of rainwater harvesting in a country which gets rain for only 100 hours of the 8,760 hours in a year. They knew that all the rain of the year could come in just one cloudburst. The solution was to capture that rain and to use it to recharge groundwater reserves for the remaining year. The answer ultimately was to use the land for storing and channelising the rain – over the ground, or under. Catching water where it falls and when it falls.

This tradition of yesterday has crucial relevance in today and tomorrow's urban India. Today, our cities get their water supply from further and further away – Delhi gets Ganga water from the Tehri dam, Bangalore is building the Cauvery IV project, pumping water 100 km to the city, Chennai water will traverse 200 km from Krishna river, Hyderabad from Manjira and so on. The

point is that the urban-industrial sector's demand for water is growing by leaps and bounds. But this sector does little to augment its water resources, it does even less to conserve and minimise its use. Worse, because of the abysmal lack of sewage and waste treatment facilities, it degrades scarce water even further. Groundwater levels are declining in urban areas as people bore deeper in search of the water that municipalities cannot supply.

In this way, water scarcity grows. The real tragedy is that when it does not rain, a city cries for water; when it does rain, it cries again because of floods.

In new India, the water imperative is that cities must begin to value their rainfall endowment. This means implementing rainwater harvesting in each house and colony. But it also means relearning about the hundreds of tanks and ponds that built, indeed nourished, the city. Almost every city had a treasure of tanks, which provided it the important flood cushion and allowed it to recharge its groundwater reserves. But urban planners cannot see beyond land. So, land for water has never been valued or protected. Today, these water bodies are a shame – encroached, full of sewage, garbage or just filled up and built over. The city forgot it needed water. It forgot its own lifeline. It lost the knowledge of how to value the raindrop.

Builders and architects have simply never been taught how to hold water. They have been trained to see water as waste and to build systems to dispose it as fast as possible. Of course, given the sheer mess of urban India, even the stormwater drains (where they exist) have become conduits for sewage or are choked. A whole generation of Indians will have to be retrained to understand water once again. It is sad how quickly a society can forget its own wisdom.

It is this wisdom, this knowledge that needs to be rebuilt. Our effort in publishing this toolkit is to retrain and reskill a generation of Indians who have lost touch with nature's most precious gift – rain. My colleagues have documented experiences of individuals, communities and building associations. Most importantly, they have documented the new innovations – from the design of filters to rainwater harvesting sumps. This innovation is what society needs as it rebuilds its knowledge of living with nature. We believe this re-skilling will happen only when the community of knowledge seekers and innovators can learn from each other. Build a new science and a new art – together.

I hope that this toolkit on urban rainwater harvesting will build new experiences and new learning. Enjoy the 'magic' of making rainwater a part of your life.

Sunita Narain

Foreword

Since the 1990s, Centre for Science and Environment (CSE) has been advocating that we should learn from our traditions to develop new approaches for managing modern-day water needs. Using its publication *Dying Wisdom* (see Preface), CSE launched a campaign to 'make water everybody's business' – the premise was that every person can manage her/his water needs by using the traditional and simple technology of "catch water where it falls".

The idea caught the imagination of the people; their interest and support, in turn, pushed the government to pay attention. Today, everyone, from the common man to ministers, are talking about rainwater harvesting. Rainwater harvesting is on the political and policy framework of the country.

CSE began with a simple campaign strategy – to make households, industries, institutions, villages and urban *mohallas*, all recognise the importance and value of rainwater harvesting. We produced simple literature and organised dozens of meetings to explain the principles and practice of rainwater harvesting. In Delhi, we collaborated with citizens to build model institutions. These model projects show people how rainwater harvesting is done. The CSE building, for instance, captures every drop of rain that falls on its premises.

Once people are interested in the idea, they then want to know how to do it. We provide free technical guidance to citizens every week. We regularly conduct workshops for builders, architects, water administrators and other groups to acquaint them with water harvesting technologies. We collaborate with local agencies to help them set up resource centres that are a repository of information on water harvesting. These 'Rain Centres,' as we call them, have live demonstration facilities to show how water can be harvested in an urban context. We have produced manuals to help citizens implement rainwater harvesting in their houses or offices.

CSE water researchers have scoured the country to identify good examples of urban rainwater harvesting efforts. We wanted to see what has happened to the idea we had sown way back in 1996. We were blown away by what we saw – the sheer dedication and the innovation of ordinary people was awe-inspiring. We saw how rainwater is being used to address a variety of water problems – to supply water to *balwadis* in slums, to improve water quality, to provide high quality water for cooking and drinking, to reduce water bills, in general, to provide water security. There were examples of ordinary citizens having come together to regenerate community water assets such as temple

tanks and urban lakes. We also came across entrepreneurs who are manufacturing filters and other components and consultants who help citizens implement rainwater harvesting. It was really heartening to see that in several cities, mainstream architects have branched off into designing water harvesting and wastewater recycling systems.

The government has done its bit to help citizens implement rainwater harvesting. There are municipal bye-laws in many cities that make it mandatory to make rainwater harvesting structures an integral part of the building. Some cities also provide incentives – Delhi and Indore, to name a few. We also came across a bank, the State Bank of Hyderabad, that provides loans for building rainwater harvesting structures. Legislators use MLA or MP funds to help implement rainwater harvesting.

All this is good, but is it enough? Much more can be done and should be done by the government. Citizens are contributing more than their share. It is time that municipal and other government bodies made determined efforts to regenerate every urban water body, hold rainwater in every urban green space and harvest rainwater in every government building. If we have to make our cities Rain Cities, the government needs to step up to the next level of harvesting and holding all the water that falls on our cities.

We are grateful to all those who have shared their case studies with us, patiently answered all our queries and provided data, drawings and photographs. We had collected more than 80 case studies from across the country, but could not use all of them due to paucity of space. The remaining case studies will be put up on our website.

Gita Kavarana

Content

1

SECTION

Introduction

The art and science of catching water where it falls is ancient wisdom, but one which is dying. Traditionally, most Indian cities had developed an intricate system of harvesting rainwater through tanks and lakes. Urban water bodies served to soak up rainwater in the cities and were the primary sources of water supply. In cities on riverbanks they served as flood cushions and in deltaic cities like Kolkata urban water bodies served as a means to treat wastewater.

The technology of rainwater harvesting has been used since ancient times but is today ignored in favour of modern systems, only a couple of hundred years old. There has been little effort to study and improve the technology despite its great potential to provide water on a sustainable basis. In urban areas, rainwater falling within individual houses, mainly using rooftops as catchments, can be harnessed.

If we can revive this traditional wisdom of catching and using rainwater and reinforce it with modern science and technological inputs, we can surely address modern day water problems. Rainwater can be collected from rooftops of buildings, playgrounds and parks, roads and flyovers and urban forested areas. These diverse forms of rainwater harvesting serve different purposes ranging from drinking, non-potable uses, groundwater recharge, to address flooding and to improve quality of groundwater.

- Most cities in India have to deal with depleting water supply, marked by falling groundwater levels, vanishing water bodies, severe pollution and urban floods

- With their own supplies drying up, cities are forced to source water from further and further away. This is expensive

- City planners usually ignore a powerful source of water that they can have easy access to – rain

- Rainwater and run-off can be harvested on the simple premise of 'catching water where it falls'. It can be collected and stored, or conveyed to the aquifer to recharge groundwater

- Rainwater harvesting (RWH) is gradually being taken up by citizen's groups and municipalities aided by legislation that makes it mandatory. The first such legislation was laid out for the city of Chennai after the drought of 1992-93. Detailed specifications for structures were published by the Madhya Pradesh government as early as 1984

- A prospective rainwater harvester has help on hand. Many municipalities have RWH cells which provide information and technical advice. Financial assistance under the Jawaharlal Nehru Urban Renewal Mission is available. Small personal loans too can be availed

- A fresh multi-pronged impetus is necessary to take RWH forward: pricing incentives for RWH, disincentives to discourage water wastage, regeneration of water bodies, RWH in public buildings, colonies and green areas

01

Urban India's water crisis

Water is what urban India is fighting for today. Cities across the country – from Chennai in the south to Shimla in the northern hills, from Rajkot in the west to Cherrapunji in the north-east – are facing the crippling effects of acute water scarcity.

There is hardly any city that can boast of a 24-hour water supply (see Table 1.1: *Water availability*). Groundwater tables are falling rapidly, centuries-old water bodies have disappeared or are severely polluted, and urban floods are becoming a regular phenomenon during monsoons. In addition to this, most of our rivers have become carriers of urban filth.

This scarcity-pollution tango is giving rise to a nightmarish scenario in which urban populations – mainly the urban poor – are at the receiving end. Let us take a look at the various facets and factors that are fanning this crisis.

Table 1.1: Water availability

Sharp fall in two decades across Indian cities

City	Early 1980s (hrs/day)	Early 1990s (hrs/day)	Early 2000s (hrs/day)
Chennai	10-15	8-10	1.5
Vishakapatnam	20-24	10-12	1-4
Hyderabad	15-24	1-5	1-2
Bengaluru	20-24	5-10	2-4
Delhi	10-12	8-10	1-2
Bhopal	8-10	4-6	1-2
Rajkot	1-2	1	Half an hour on alternate days

Sources: Administrative Staff College of India, Hyderabad & Centre for Science and Environment, New Delhi

A DESTRUCTIVE URBAN WATER PARADIGM

How do modern cities source and use water? Our planners don't make rain-friendly cities. Most of the rain that falls in cities is allowed to drain away as run-off; this rain could have recharged the groundwater, but with the increase in built-up areas within cities, the land available for recharge is getting drastically reduced, even as the groundwater is heavily abstracted.

This situation is worsened by the extraordinary value attached to real estate, resulting in the conversion of natural recharge areas such as lakes, ponds and wetlands into built-up areas.

While the rainwater is thus wasted, city administrations go to great efforts to bring water at a huge cost through pipes and tankers. Much of this water is abstracted from far-off areas – giving rise to potential points of conflict with the users of this water in those places (see Box: *Water from afar*).

RAPID URBANISATION

India's urban population has grown almost five times between 1951 and 2001. By 2026, an estimated 38 per cent of the total population will be urban.[1] As a result, there is tremendous pressure on all resources, including water. Cities are demanding and consuming more water, and also wasting a lot of it in the process.

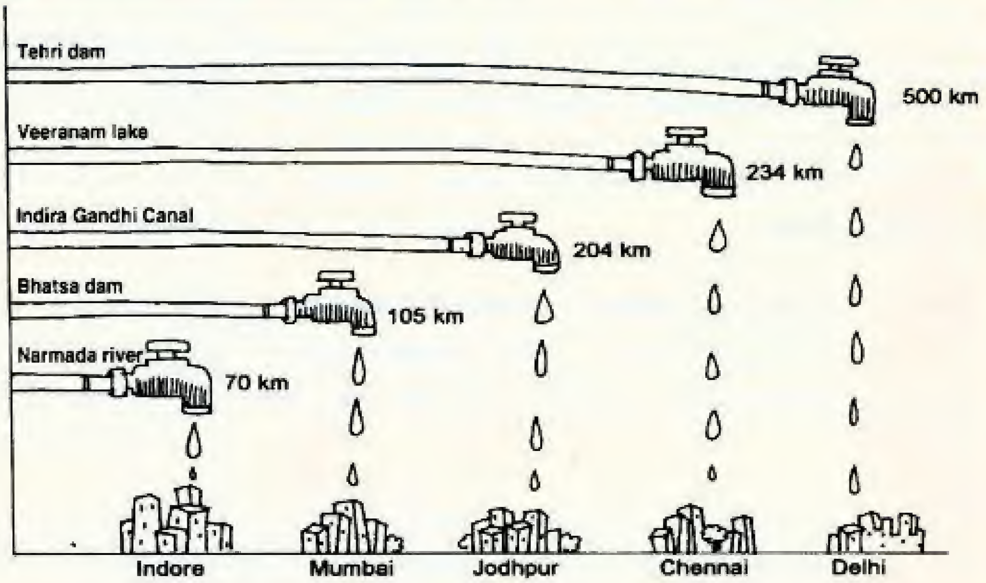
Water from afar

Metropolitian cities freeload on their hinterland

The Delhi government goes far into the neighbouring states in search of water. In addition to taking out all the water from the Yamuna that flows through the city, more Yamuna water is brought through the Western Yamuna Canal from Hathnikund/Tajewala in Yamuna Nagar district of Haryana state. Water is also obtained from the Ravi-Beas storage at Bhakra dam in the Punjab, from the Bhagirathi river storage at Tehri dam in Uttarakhand, as well as from the Ganga through the Upper Ganga Canal in Uttarakhand and Uttar Pradesh. All this is still not enough. Groundwater is also abstracted both by the Delhi Jal Board as well as by residents.

Similarly, Chennai brings water from Veeranam lake, Mumbai from Vaitarna and Bhatsa, Indore from the Narmada river and Jodhpur from the Indira Gandhi Canal.

Figure: Distant water sources



More consumption means generation of larger volumes of wastewater. An estimated 80 per cent of the water we use is discharged as wastewater. Governments are simply failing to keep up – both with the demand for freshwater and the need for treating wastewater. Unmet demand results in increasing withdrawals from the ground (*see section on groundwater below*), while untreated wastewater pollutes surface water sources as well as groundwater.

WATER POLLUTION IN URBAN AREAS

In 1978-79, India produced 7 billion litres a day (BLD) of sewage[2]. Within 20 years, this had increased nearly five-fold to 38 BLD. But the treatment capacity is a meagre 12 BLD[3]. The untreated sewage goes back into the rivers which are also the sources of water for the next city or town downstream. As a direct result of this, the quality of groundwater is also deteriorating, with problems ranging from excess of nitrate and total dissolved solids (TDS) to arsenic and fluoride contamination (see Box: *Potable groundwater*).

Besides rivers, most other surface water bodies – lakes, ponds, wells – have also become receptacles for urban sewage, and are disappearing. Researchers at the Indian Institute of Science, Bengaluru, have determined that their city had 51 lakes in the early 1970s; by the end of the century, this number had plummeted to a mere 17, of which only 14 could be considered 'alive'.[4] In Hyderabad, there were 932 water bodies in 1973; by 1996, 834 were left.[5]

In the case of Delhi, even determining the number of water bodies took some time, effort and coaxing by the judiciary (see Box: *Whither water bodies?*).

Potable groundwater

Rainwater is first collected and stored and subsequently used to dilute groundwater

At Kokawad Ashram in Jhabua, Madhya Pradesh, a residential school for tribals, rainwater harvesting has been used to dilute the high fluoride levels in groundwater. The rain falling on the rooftop of the school building is stored in a 75,000 litre ferrocement tank and used for this purpose. The groundwater as well as the stored rainwater is pumped to overhead tanks where they are mixed and used for drinking and cooking. The diluted groundwater is potable.

This is the simplest and most cost-effective way to address fluoride contamination. There are fluoride filters of various design, but these do not work on a sustainable basis since they require sustained monitoring and maintenance. In this scenario rainwater from storage tanks are increasingly being used to recharge shallow dugwells.

Whither water bodies?

Delhi found it hard to tally numbers

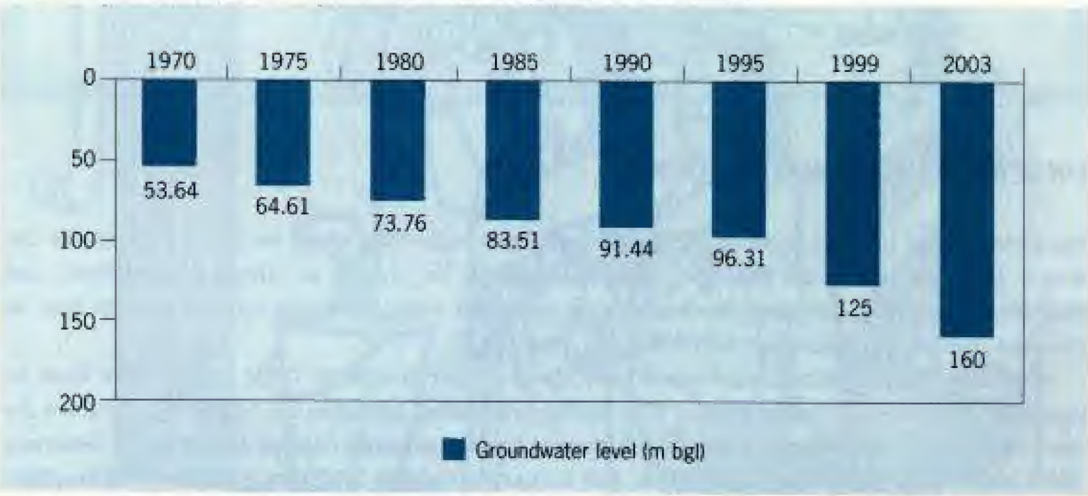
In 2001, the Delhi Municipal Corporation had come up with a list of 177 water bodies in the capital; this contention was challenged, since an earlier report had identified 355. Subsequently, the Delhi High Court ordered a survey, which came up with a figure of 508 water bodies in 2002. However, there were several discrepancies in this list too. A new committee was formed for yet another survey, which showed that there were 794 water bodies in Delhi.

But several prominent water bodies were missing even from this survey. A water body in Sainik Farms that was listed in 2002, for instance, was not included in the second list as the surveyors were unable to find it. A lake near the Indira Gandhi stadium was also missing. Over half of the natural lake of Mayapuri was found to have been taken over for construction of a common effluent treatment plant (CETP) even as the Public Works Department claimed that no such lake existed in its records.[1]

GROUNDWATER DEPLETION

In cities across the country – Chennai, Bangalore to Kolkata and Ahmedabad – rapid decline in groundwater levels have brought on unanticipated problems. In Chennai, over-extraction of groundwater in the Minjur well field has resulted in rapid ingress of seawater, which extended from 3 km inshore in 1969 to 7 km in 1983 and 13 km in 2007.[6] In Kolkata, reckless groundwater exploitation has changed the direction of the flow of the water and resulted in land subsidence in the central and southern parts of the city. In Ahmedabad, groundwater levels have declined from less than 20 metres below ground level (m bgl) in the 1960s to more than 160 m bgl in 2003 (see Graph 1.1: *Decline in groundwater level, western periphery of Ahmedabad*).[7]

Graph 1.1: Decline in groundwater level, western periphery of Ahmedabad



Source: Parth Shah 2005, 'Strategy to revitalise urban water bodies: case of semi-arid Gujarat', International Institute for Geo-Information Science and Earth Observation, The Netherlands, March

URBAN FLOODING

While on one hand there is severe water shortage, on the other, cities are increasingly drowning under swirling flood waters. In the last decade alone, a number of incidences of urban floods were reported – Mumbai (9), Ahmedabad (7), Chennai (6), Hyderabad (5), Kolkata (5), Bengaluru (4) and Surat (3).[8]

In many cities, water bodies and natural drainage channels have been filled up and encroached upon, thus leading to flooding. Besides this, the crumbling drainage systems in many towns, built many years ago, have not been expanded, modernised or maintained. This aggravates water-logging and flooding and leads to health hazards in its aftermath.

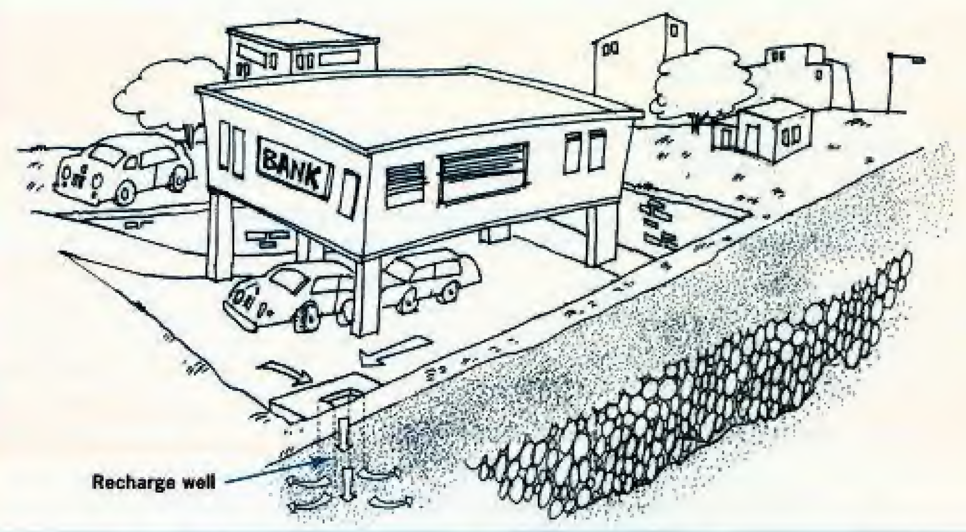
The flood waters can be harnessed and used (see Box: *No more flooding*).

No more flooding

A bank shows the way

The Karnataka Bank branch in Kuvempu Nagar, Mysore, used its basement for parking vehicles. In the rainy season, the basement would be completely flooded. To address the problem, the bank built an underground tank to collect the flood water which was pumped out into the stormwater drains.

To put the water to good use the bank authorities decided to recharge the aquifer with the collected rainwater and a recharge borewell was sunk within the tank itself. During the monsoon at least 10,000 litres percolates into the aquifer every day. As the water level in the aquifer rose, there was no flooding in the basement. The bank staff say that the quality of water from the borewell used by them has improved. The hardness has reduced.

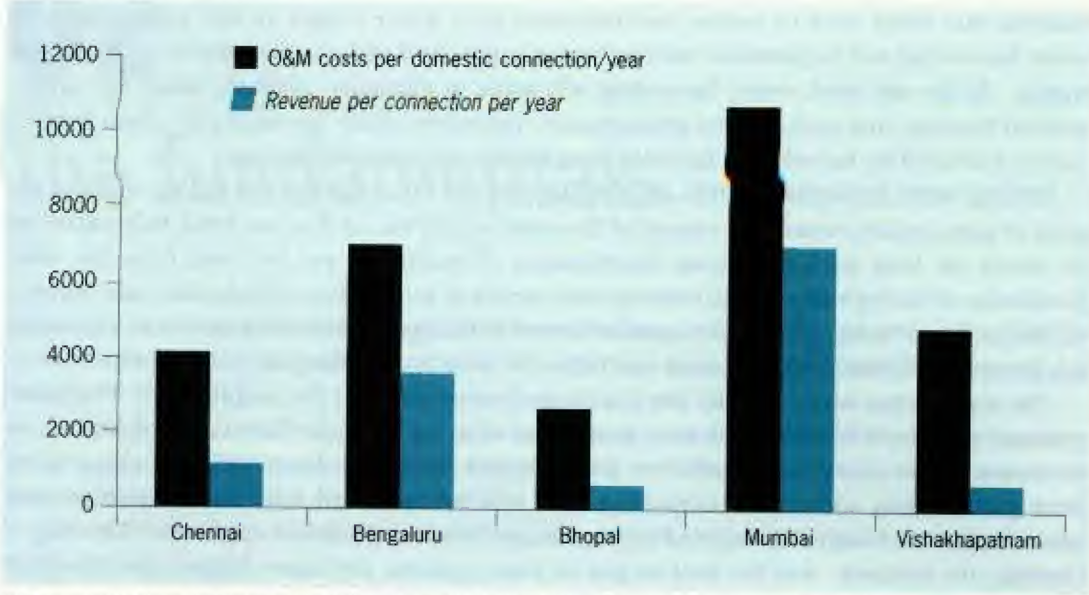


UNDERPRICING IN WATER SUPPLY

Supplying water to cities is an expensive proposition – especially when we pay a pittance for the water that we get. For instance, Chennai spends Rs 4,003 as annual operations and maintenance (O&M) cost per connection per year, but collects barely 25 per cent of that as revenue from every domestic connection per year.

Similarly, Bhopal manages to collect only about 19 per cent of its O&M expenditure from its domestic connections. Municipalities also spend substantial amounts on capital expenditure for each connection, but charge very little. Chennai has an average capital expenditure (between 2002-2006) of Rs 10,080 per connection, but it charges only Rs 1,930 for every new connection. Mumbai has a capital expenditure of Rs 3,790 per connection and charges a mere Rs 910 for

Graph 1.2: Cost-tariff shortfall



Source: Adapted from *Benchmarking and Data Book of Water Utilities in India*, Asian Development Bank, 2007

every new connection (see Graph 1.2: *Cost-tariff shortfall*).

The distribution is as skewed as the pricing. Official supply rarely reaches the poor, and the benefits of the low prices are usually reaped by the rich.

WAY FORWARD

Rainwater harvesting is an idea whose time has come. Today, there is a great deal of interest in society to take responsibility for their water. There are innovations in capturing and using rainwater in every city. The government too, is following the trend and has brought in legislation and measures to cajole or force citizens to harvest rainwater.

To cater to the modern day urban water demands of a growing urban population, cities have to use a variety of methods to harvest, store and use rainwater. From micro-catchments of

rooftops to macro-catchments of urban lakes, there a wide variety of urban water harvesting methods that cities need to employ and maximise their water supply. At the household level, water harvesting can supplement existing water supply and reduce dependence on municipal supply. At the city level, water harvesting will serve to maximise available water for supply, prevent flooding, and recharge the groundwater. Therefore, water harvesting in urban habitats can be practised by households, factories, institutions and the governments.

Rooftop water harvesting affords an affordable means of accessing good quality water at the point of consumption, where the control of the water supply lies at the user level. Rainwater can be stored for long periods without deterioration of quality as can be seen from the wide prevalance of storing rainwater in underground tankas in arid regions of Rajasthan and Gujarat. In urban cities of India today, where multi-storeyed buildings are becoming the norm, rainwater can be collected from the roof, paved and unpaved areas and recharged to the aquifer.

The acute urban water scarcity has forced the government and the people to act. The public response to water harvesting has been positive all over the country. Concerned citizens across the country have also come together to protect urban lakes and water bodies in many cities. State governments and city municipalities have enacted laws and introduced incentives and other measures, which have served to encourage citizens to harvest rainwater. The city of Chennai, for instance, was the first to put in place systems to ensure large-scale rainwater harvesting. Other cities have followed suit with similar legislation.

02

The fundamentals

Rainwater harvesting (RWH) involves the capture, storage and use of rainwater and run-off for domestic or agricultural purposes. Essentially, RWH systems use the principle of conserving rainwater 'where it falls', in the process recharging groundwater.

In urban areas, rainwater can be collected from the roof, paved and unpaved areas of a house, a block of flats, a colony, a park, a playground, parking areas, schools, office complexes lakes and tanks.

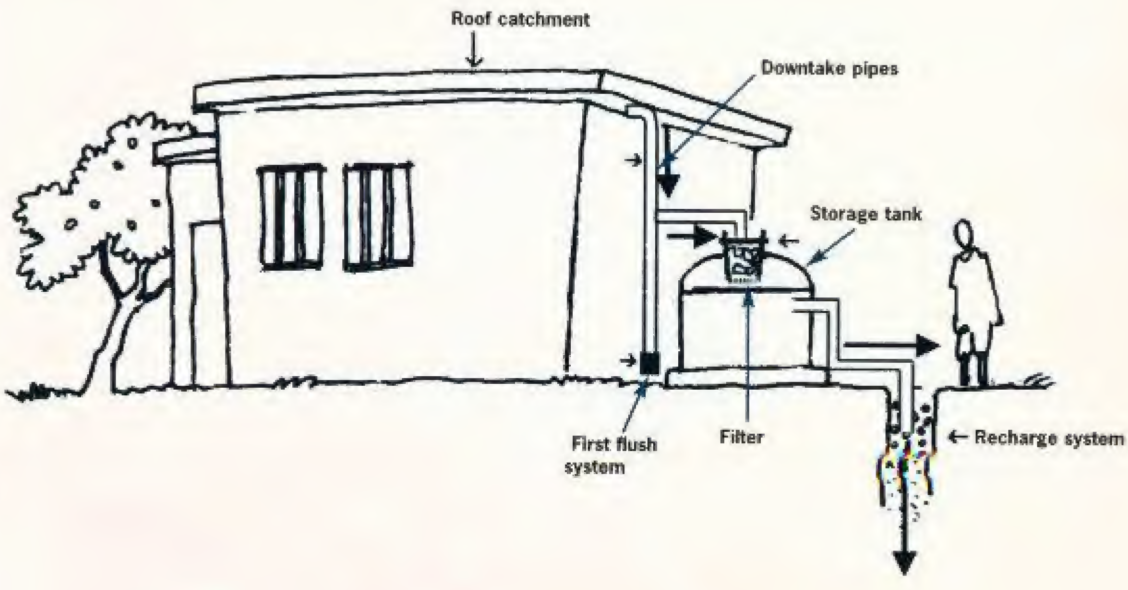
There are two ways of using the harvested rainwater, through (1) *storage* in receptacles, and to (2) *recharge* into the aquifer.

ELEMENTS: URBAN RAINWATER HARVESTING

A few, basic elements are common to all RWH systems (see Figure 2.1: *Model of a simple RWH system*):

1. the *catchment area* where the rain falls;
2. the *conveyance* or *conduit system* that channels the flow of water in a given direction;
3. the *first flush* (a valve that ensures that run-off from the first spell of rain is flushed out and does not enter the system) and the *filter system*; and,
4. the *storage area*, consisting of tanks/receptacles.
5. the recharge area, where the harvested rainwater is used to replenish the groundwater.

Figure 2.1: Model of a simple RWH system



CATCHMENT

The catchment is a structure or land area that is used to collect rainwater and drain run-off. It could be either paved or unpaved (see Table 2.1: *Catchment surfaces and their characteristics* and Figure 2.2: *Types of catchment*).

Paved area catchments: These are smooth surfaces, clean and more impervious to seepage. These surfaces collect greater quantity and better quality of water. These could be roofs, driveways, parking areas, courtyards and roads.

Roof catchments have the maximum run-off and are generally considered clean and safe. Yet, water harvesters should keep in mind possible contaminants. In India, roofs in urban areas are mostly made of reinforced concrete cement (RCC), but roofs can be laid with galvanised iron (GI) sheets, tiles or slates. At times, roofs could also be thatched.

Concrete or cement roofs retain more dust and dirt than metal roofs, which are smooth. In the case of GI roofs, rainwater may capture zinc, the coating material. If the rain is acidic, metal roofs used in industrial areas will leach metals into water. Similarly, paints used on metallic roofs may leach out toxic chemicals such as lead or chromium. This is why certain materials must not be used when installing RWH systems (see Box: *Roof catchments: what not to use*).

When rainwater is collected at *driveways, parking areas, courtyards* and on *roads*, water is conveyed through gully traps, channels, stormwater drains and sometimes collected at the end of natural slopes. This can be used for groundwater recharge or for non-potable uses such as gardening. The quality of water collected in these places is not as good as that of a rooftop collection.

Roof catchments: what not to use

Tar felted roofs: A source of biological and heavy metal contamination.

Asbestos sheets: Weathered and leached fibres of asbestos are highly toxic.

Chemically treated roofs: Chemicals used for water-proofing have high concentration of heavy metals.

Painted roofs: Most paints contain lead, zinc and chromium. Over time these may dissolve with rainwater, contaminating stored rainwater.

Treating catchment surfaces

Catchments can be improved with different kinds of treatment to improve their water collection efficiency. Ground or land surfaces can be improved by clearing or altering vegetation cover, increasing the slope of the land and also by soil compaction. Roofs can be treated with lime *surkhi* and cement mortar to improve collection efficiency.

Figure 2.2: Types of catchment

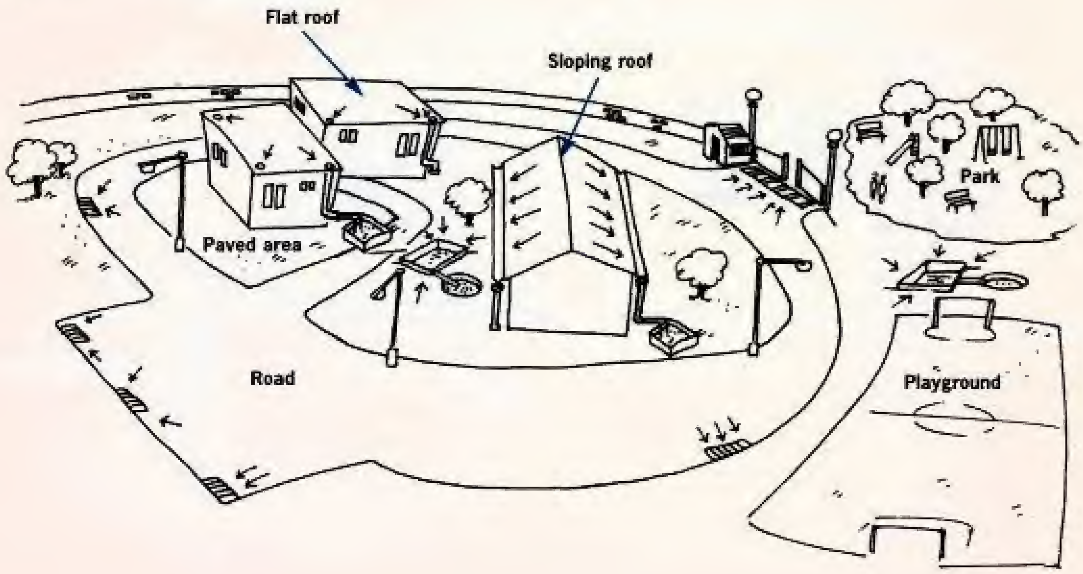


Table 2.1: Catchment surfaces and their characteristics

Clean catchments are necessary as they yield maximum run-off for harvesting

Types of surfaces	Materials	Characteristics
Paved surfaces		
Flat roofs	Concrete, cement sheets, china chips, bricks with cement lining	Safe and clean catchments are least prone to contaminants. They also yield maximum run-off available for harvesting
Sloping roofs	GI (galvanised iron) sheets, Mangalore tiles, slate, fibre sheets	As above
Treated roof surfaces	Thatched roofs covered with polythene sheets	Improves water collection
Driveways, courtyards, pavements, internal roads	Cement, concrete, tiles	Collects good quantity of rainwater of reasonable quality, depending on maintenance of the site
Highways, roads, parking lots	Asphalt, concrete, bricks, stones	Can be used after installing oil and grease traps and other filtration devices
Unpaved surfaces		
Lawns, parks, gardens from large open spaces	Soil, grass or vegetation	Substantial amounts of water can be recovered
Playgrounds, courtyards	Hard, packed soil	Water collection efficiency will be more than on vegetation covered surfaces

Source: Centre for Science and Environment (CSE), New Delhi

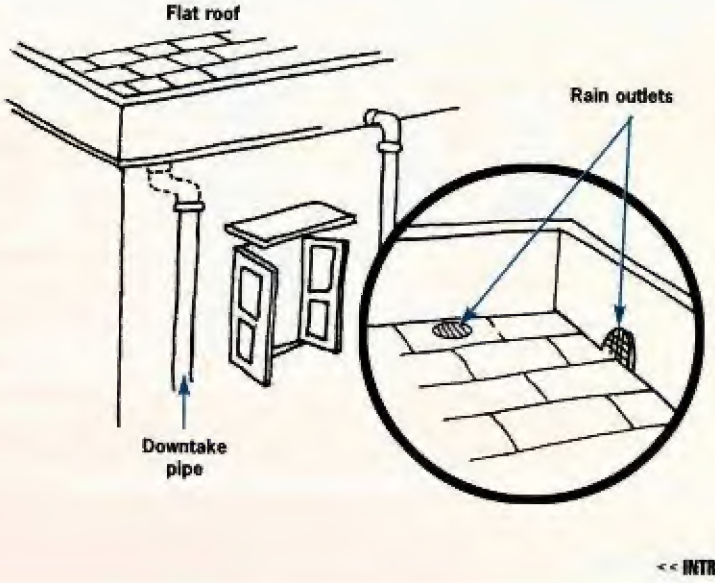
Unpaved area catchments: Unpaved areas found in gardens, lawns and playgrounds permit more infiltration and less run-off. These contain more impurities and silt. Water from unpaved areas is mainly used for groundwater recharge.

CONVEYANCE SYSTEMS

Conveyance or conduit systems direct water flow from the catchment area to the storage area. A carefully designed and constructed conveyance system can divert more than 90 per cent of all the water that falls on to the roof.

Flat roof conveyance: Flat roofs have *rain outlets* from which pipes lead out to stormwater drains and sewers, or simply terminate at the ground level (see Figure 2.3: *Roof outlet*). The

Figure 2.3: Roof outlet



downtake pipes can be connected to rainwater storage cisterns or to recharge systems. downtake pipes can be concealed or attached to the walls of buildings. These pipes are made of mild steel (MS) sheets, polyvinyl chloride (PVC), bamboo or other suitable material. In buildings where the downtake pipes are concealed and lead directly to the stormwater drain, fresh conveyance systems will have to be built to carry the water.

Sizing: The diameter of the downtake pipe will be directly proportionate to the roof area and inversely proportionate to the rainfall intensity. As a thumb rule, for a roof area of approximately 40 sq m where the rainfall intensity is 100 mm/hour, the diameter of the downtake pipe will be 100 mm.[2]

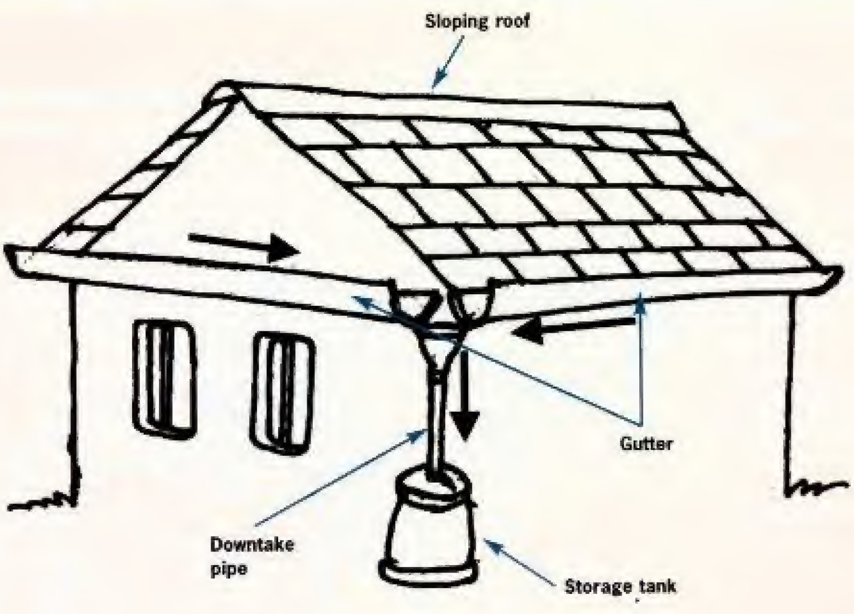
Sloping roof conveyance system: In the case of sloping roofs, *gutters* built under the eaves of the roof carry the run-off (see Figure 2.4: *Harvesting rain from a sloping roof*). Downtake pipes are attached to the gutters.

Gutters, which run all along the edge of the roof, can be semi-circular or rectangular and made from a variety of materials ranging from bamboo, cement or wood to GI sheets. While organic materials like bamboo are initially cheaper, they will cost more to maintain.

Gutters need to be supported with *brackets* so that they do not sag or fall off their hinges when loaded with water. For large sloping roofs, a *splash-guard* could be useful. It is a long sheet of metal, bent at an angle and nailed to the roof in such a way that the lower half of the sheet fits directly into the gutter. This way water does not overshoot the gutter.

Sizing: Gutters should be sized to direct the flow during the highest intensity rain without loss of water. As a thumb rule, there should be 1 sq cm of gutter cross-section for every 1 sq m of roof area.[1] For large roofs such as in schools, a gutter cross-section of 98 sq cm is recommended for a roof area of about 400 sq m. A gutter gradient of 1:100 will ensure that water is transported without overflow losses, splash or spillage with less chance of gutter blockage from leaves and other debris.[3]

Figure 2.4: Harvesting rain from a sloping roof



FILTER SYSTEMS

Rainwater is often contaminated with dust, leaves and twigs, bacteria, particulates and dissolved gases. It is necessary to install filters both for storage and recharge systems. There are several ways of filtering contaminants. There are simple systems that keep out leaves and debris and remove the first flush of rainwater. More complex systems filter out bacteriological and other dissolved contaminants.

(See Chapter 8, Section 2 for details on filters and first flush devices.)

STORAGE STRUCTURES

Storage tanks are available in diverse materials ranging from cast iron sheets and PVC to RCC structures. Storage tanks can also be made of ferrocement, an inexpensive material, essentially a thin cement mortar reinforced with wire mesh. Overground tanks are less expensive than underground tanks, as excavation and costs of stronger reinforcing can be avoided.

One can also have more than one storage tank, depending on the site conditions. This also makes it easier for maintenance and repairs as some tanks can be used while the others are shut down for maintenance.

(See Chapter 6, Section 2 for ways of using storage structures for rainwater harvesting.)


SUSHMITA SENGUPTA / CSE

Ferrocement is an inexpensive material to make water storage tanks

RECHARGE STRUCTURES

In urban situations space is a constraint when making storage arrangements. In India, the rainy season is very short and this is another factor that does not support storing large quantities of harvested rainwater. Therefore, recharging the aquifer is a better way of harvesting rainwater, especially since water tables have been declining.

Rainwater may be charged into the aquifers through *recharge pits, recharge wells, recharge trenches, and dry dugwells/borewells*. As in the case of storage, there must be a system to filter out sediments and other debris, before the water enters the recharge structure. Desilting chambers serve this purpose.

(See Chapter 7, Section 2 for ways of using recharge structures for rainwater harvesting.)

STORMWATER DRAINS

Harvesting water from stormwater drains is receiving more attention in India today since it can control the annual flooding in cities; at the same time, it can supplement the rainwater collected from rooftops.

As India receives its annual rainfall within a concentrated span of about three months, the rainfall received in this short period is greater than what can be collected through rooftops. The run-off from the city roads, drains, creeks and public spaces, that receive a large amount of rainfall, can be channelled into stormwater drains, to recharge groundwater.

Stormwater harvesting schemes are best incorporated within new projects, as the costs are substantially lower than retrofitting them into existing systems. Good stormwater management will play an important part in controlling urban floods during monsoons. It is also a good means to dilute pollution of rivers.

03

Policy and practice

Urbanisation and industrialisation have increased water use as well as the generation of wastewater. As urban local bodies struggle to meet the growing demand for water, there has been a resurgence of interest in rainwater harvesting (RWH) in cities, backed by supportive policies from municipalities, state and the central governments.

FIRST POLICY STEPS

Almost all states in India have legislated to make RWH mandatory in cities; these legislations that mostly apply to new buildings. Some city municipalities have moved forward and devised penalty clauses and even institutionalised financial incentives and disincentives to induce people to take up rainwater harvesting. Although their effectiveness depends on strict enforcement, such measures have served to catalyse water conservation efforts on a wider scale.

At least a number of important city municipalities have set up RWH cells to provide information and technical advice. In almost all major cities, non-governmental organisations (NGOs), schools and other institutions have taken up RWH on a large scale.

Financial assistance for RWH projects has also been forthcoming from the central government. Funds under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) are available to urban local bodies for:

- construction and improvement of drains/stormwater drains,
- preservation of water bodies,
- revision of bye-laws that make RWH mandatory in all buildings and adoption of water conservation measures,
- institution of bye-laws for reuse of recycled water.

CHENNAI SHOWED THE WAY

Chennai, in Tamil Nadu, was one of the earliest cities to take up RWH on a large-scale. After the severe drought of 1992-93, Chennai Metro Water worked out a 'statutory understanding' with the Chennai Metropolitan Development Authority (CMDA) and Chennai Corporation that planning permission applications for buildings of 'ground +3 floors' and above would be accepted only if they included a plan for RWH systems.[1]

Despite this directive, buildings continued to be constructed without RWH installations. When the next big water crisis came upon the city in 2001-02, the government amended the 'Chennai Metropolitan Area Groundwater (Regulation) Act, 1987' – that covers the whole city of Chennai and 243 revenue villages around it – to make RWH compulsory for all buildings, old and new.

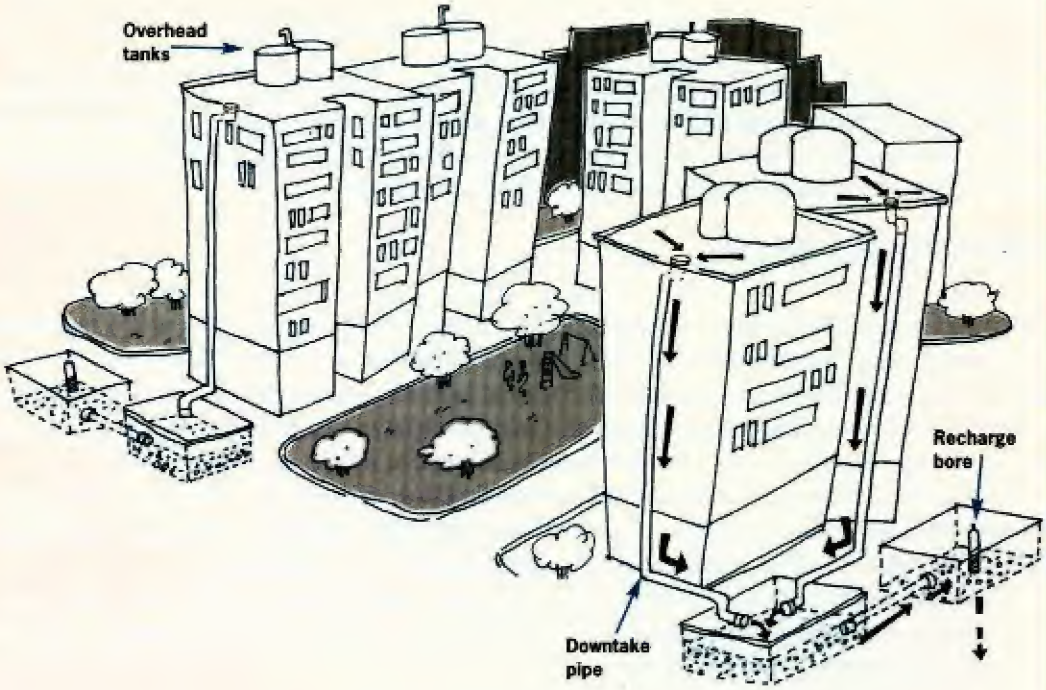
To enforce this rule, the Tamil Nadu Municipal Laws Ordinance was passed in July 2003, under which all buildings would have to install RWH systems. Where the rules were disregarded, the municipality could install it, and recover the cost from the building's owner. Under powers vested by the ordinance, municipal water supply could also be disconnected.

The Tamil Nadu District Municipalities Building Rules, 1972, was also amended to include the provisions of this ordinance, and made applicable to the entire state by making suitable changes to the municipal rules of other cities in the state. Rural areas were brought within its ambit by inserting similar changes to the Tamil Nadu Panchayat Building Rules, 1997. The ensuing regulatory environment induced builders to incorporate RWH systems in their building plans (see Case study: *Shantiniketan Residential Enclave, Madurai*).

CASE STUDY

SHANTINIKETAN RESIDENTIAL ENCLAVE, MADURAI

The rainwater harvesting system was set up to meet the regulatory requirement of the Tamil Nadu government, which made it mandatory for all buildings



This apartment complex, situated very close to the river Vaigai is spread over 6.5 acres (2.6 hectares) with 340 apartments. The builders did not anticipate any water problems in this area due to the proximity of the river and construction of the complex started in 2000. In 2002, in the backdrop of the water crisis in Chennai and legal changes in Tamil Nadu, rainwater harvesting systems were added to the blocks that had been completed.

The combined roof area of three apartment blocks is about 6,503 sq m. Rainwater from the roofs of each building is directed to three separate recharge wells.

For more information, contact:
Parmesh
Site in-charge, site office
Shanti Niketan Residential Enclave
Phone: (o) 9843326583

System details
Total rooftop area of the three blocks: 6,503 sq m
Rainwater potential: 748.9 x 6,503 x 0.8 = 44.53 lakh litres
Dimensions of the pit: 1.5 m x 1.5 m x 2 m
Cost in 2002: Rs 180,000
Year of implementation: 2002

Designed by *V R Ramnath, architect, Ashok Nagar, Madurai – 625 016*
Phone: (0452) 238-0471
E-mail: sashwath@satyam.net.in

The CMDA has also provided detailed guidelines and specifications on rainwater collection for buildings as part of the Development Regulations of the Second Master Plan of the Chennai Metropolitan Area, 2026.[2]

Chennai Metro Water has constituted a dedicated rainwater harvesting cell, which conducts awareness campaigns and provides free technical assistance to residents, and brings to their notice cost-effective solutions. Metro Water has created several RWH models with detailed designs and these have been published in brochures and booklets and are distributed to the public. A number of seminars, workshops and exhibitions have been organised involving various government agencies, NGOs and private individuals to build awareness.

A household survey conducted by CSE revealed that 92 per cent of the city's households had implemented RWH. Among them, 86 per cent were installed after the promulgation of the ordinance in August 2003, with only five per cent before 2002.

The Corporation of Chennai has constructed RWH structures as listed in Table 3.1.

Table 3.1: Rain harvesting structures, Chennai
Mostly installed after a strict ordinance was passed

Type of construction	Number
Corporation owned buildings	1,344
Fly-overs and bridges	29
Open low-lying areas	242
Road margins	945
Streets	2,698
Ponds	1
Temple tanks	16
Residential/commercial/ institutional buildings	329,959

Source: http://www.chennaicorporation.gov.in/departments/storm-water-drains/introduction.htm as viewed in November 2011

LEGISLATIVE NORMS

Some important facts on the regulatory norms for RWH from a few cities in India are given here.

CHENNAI, TAMIL NADU

What you need to know

- RWH structures are compulsory for all types of new and existing buildings: private, group-housing, multi-storeyed, government, quasi-government of all sizes.
- Building plans will not be approved if RWH is not incorporated in the plans.
- On inspection, if RWH structures are found missing, the municipal authority will construct the system and recover costs from owner/occupier of the building.
- Water and sewage connections in new buildings will not be given if RWH is not incorporated.
- When there is no RWH system, it can lead to disconnection of water supply.
- Applicable to either the owner or occupier.

Who can help you?

Chennai Metro Water and the Tamil Nadu Water Supply and Drainage (TWAD) Board have constituted separate RWH cells equipped to guide citizens on all aspects of rainwater harvesting. There is detailed information on legislations, techniques and successful RWH projects on their websites. These organisations also undertake awareness and motivational campaigns.

Contact details:

- RWH Cell, TWAD Board 1, Kamarajar Salai, Chennai – 600 005, http://twadboard.gov.in/twad/index.aspx
- Senior hydro-geologist, RWH Cell, Chennai Metro Water, No. 1, Pumping Station Road, Chintadripet, Chennai – 600 002. http://www.chennaimetrowater.tn.nic.in/

Technical designs and specifications can be found at:
http://www.chennaimetrowater.com/departments/rainwater.htm

BENGALURU, KARNATAKA

What you need to know

- Rainwater harvesting structures are compulsory for all buildings with a plinth area exceeding 100 sq m and site measuring not less than 200 sq m. They should have one or more RWH structures.
- Failure to provide for RWH attracts a penalty of Rs 1,000 per annum for every 100 sq m of built-up area.
- Building plans will not be approved if RWH is not incorporated in plans.
- Incentive of 2 per cent on property tax for five years beginning 2011.
- Applicable to the area under the Bruhat Bengaluru Mahanagara Palike.
- Deadline for RWH structures was fixed for December 31, 2011, after which the water supply was to be disconnected.
- The Karnataka government also announced a 20 per cent rebate on property tax for those constructing systems in rural areas.

Who can help you

The Bangalore Water Services and Sewerage Board (BWSSB) has a help desk and sends its technical staff to assist citizens to implement the systems. They also undertake a number of awareness programmes in schools, colleges and other institutions.

Contact details:

- Public Relations Officer, BWSSB
  1st & 2nd floor, Cauvery Bhavan, K G Road, Bengaluru – 560 009.
  BWSSB help desk numbers – (080) 233-41652, 233-48848, 233-48849
  BWSSB website has a detailed FAQ regarding laws, rules, and who can help,
  http://www.bwssb.org/rainwater_harvesting.html
- Karnataka State Council of Science and Technology
  Indian Institute of Science, Bengaluru – 560 012
  http://kscst.org.in/rwh.html

HYDERABAD, ANDHRA PRADESH

What you need to know

- Rainwater harvesting structures are compulsory for all new buildings: private, group-housing, multi-storeyed, government, quasi-government of all sizes.
- Building plans will not be approved if RWH is not incorporated in those plans.
- RWH structures shall be provided within the setback[3] as prescribed for all plots of 200 sq m and above as per rules for percolation pits, trenches, rooftop water collection and storage and filters.
- At least 10 per cent of additional property tax every year will be imposed as penalty by the sanctioning authority till the regulatory conditions are fulfilled.
- On inspection, if RWH has not been provided for, the municipal authority will construct the system and recover costs from the owner or occupier. Water supply can also be disconnected.
- A rebate of 10 per cent in property tax will be given to those who undertake both RWH and wastewater recycling.
- Financial assistance can be obtained (see Box: *Personal loans for rainwater harvesting*).

Contact details:

- RWH Cell, Hyderabad Metropolitan Water Supply and Sewerage Board,
  Khairatabad, Hyderabad – 500 004,
  http://www.hyderabadwater.gov.in/wwo/UI/rainwaterharvesting.aspx

03

POLICY AND PRACTICE

Personal loans for rainwater harvesting

The State Bank of Hyderabad provides personal loans of upto Rs 25,000 for constructing rainwater harvesting structures under the Varun Mitra scheme which is available for individual home owners, building societies, apartment complexes, co-operative housing societies, as well as houses under construction. The loan is treated similar to a housing loan and is repayable over a 36-month period starting a month after financing. For new home owners, the amount is clubbed with the home loan. No margin is required and no processing fee is charged.[1]

MUMBAI, MAHARASHTRA

What you need to know

- Rainwater harvesting structures are compulsory for all types of new buildings – private, group housing, multi-storeyed, government, quasi-government – on plot size of 300 sq m and above. Specifications for structures have also been notified.
- Building plans will not be approved if rainwater harvesting is not incorporated in plans.
- Rs 1,000 will be levied for every 100 sq m plot where RWH has not been undertaken.[4]
- In 2008, the Brihanmumbai Municipal Corporation (BMC) also notified that the municipality would only supply 90 litres per capita daily (lpcd), which meant that there wouldn't be enough supply for flushing or gardening purposes. The aim of this move was to force people to undertake rainwater harvesting or recycling of wastewater for flushing or gardening.

Who can help you

The BMC's rainwater harvesting (RWH) and water conservation cell provides technical help. More than 25 model projects have been undertaken by the municipality. The cell also undertakes awareness campaigns.

Contact details:

- RWH and Water Conservation Cell, Municipal Corporation of Greater Mumbai
  Municipal Head Office Annexe, 3rd Floor, Mahapalika Marg, Mumbai – 400 001,
  http://www.mcgm.gov.in; E-mail: aerwhbmc@yahoo.co.in

BHOPAL AND INDORE, MADHYA PRADESH

What you need to know

- Rainwater harvesting structures are compulsory for all new buildings: private, group-housing, multi-storeyed, government, quasi-government on plot size of 140 sq m and above.
- Building plans will not be approved if RWH is not incorporated in plans.
- A rebate of 6 per cent on property tax for the year in which the system was built is available in Indore and Bhopal.
- The Bhopal Urban Development Authority's notification No. 2583 15/2009 dated October 27, 2009 mandates that for all new buildings of more than 140 sq m plot size, builders must deposit funds for rooftop water harvesting (see Table 3.2: *Security deposit*). On the completion of the building, together with the rooftop harvesting structure, the deposit will be refunded.
- The Madhya Pradesh government has instituted specifications and guidelines for building RWH systems for different types of

Table 3.2: Security deposit
Refunded after completion of the harvesting system

Plot size	Deposit amount
Between 140 and 200 sq m	Rs 7,000
Between 200 and 300 sq m	Rs 10,000
Between 300 and 400 sq m	Rs 12,000
More than 400 sq m	Rs 15,000

Source: Notification No 2583 15/2009, October 27, 2009, Bhopal Urban Development Authority

Specifications for rainwater harvesting

Under Annexure N of Madhya Pradesh Bhumi Vikas Rules, 1984, Rule 78 (4)

Appendix N-1: Rainwater harvesting through percolation pits (individual house)
"Dig a number of 3 m deep and 30 cm dia percolation pits of 3 m intervals around the plinth fill them up with broken bricks and pack the top 15 cm with river sand. Erect 7.5 cm high dwarf walls entrance to facilitate recharge."

Appendix N-2: Rainwater harvesting through pebble bed (building complexes)
"On the three sides along the inner periphery adjoining the compound wall, dig 1 m wide pit to a depth of 1.5 m and fill it with 5-7.5 cm sized pebbles. Let the rainwater falling on the terrace flow into this pebble bed."

Appendix N-3: Rainwater harvesting through service-cum-recharge well
"Provide well of 1.2 m dia for a depth of 10.0 m and divert the rainwater from the terrace into the well through rainwater downtake pipes. Divert the rainwater falling around the open space surrounding the building to the frontage wherein a gutter is provided for a depth of 1.0 m and a width of 0.6 m with perforated slabs. The rainwater collected in the gutter in front of the entrance is discharged into another recharge well of 1.2 m dia for a 10.0 m depth, provided through necessary piping arrangements."[1]

buildings (see Box: *Specifications for rainwater harvesting*).

- Though Chennai is symbolic of large-scale urban rainwater harvesting systems, the town of Dewas near Indore in the parched Malwa region of Madhya Pradesh has been a centre for RWH innovations such as the low-cost 'Dewas filter' (see Box: *Water scarcity induces innovation*).

Contact details:

- ***Bhopal***
  Officer-in-charge
  City Planning Department
  Building Permission Section
  Bhopal Municipal Corporation
  6 No Bus Stop, Shivaji Nagar
  Bhopal – 462 016
  http://www.bhopalmunicipal.com/

To hire contractors authorised to construct RWH systems by the Bhopal Municipal Corporation, please look at,
http://www.bhopalmunicipal.com/Hindiversion/Rain%20Water.htm

- ***Indore***
  City engineer's office
  RWH Cell
  Indore Municipal Corporation
  Palika Plaza, MTH Compound
  Indore
  http://www.imcindore.org/index.jsp

Water scarcity induces innovation

The story of Dewas and its 'filter'

Dewas sits on the Malwa plateau and the clayey soil allows for little recharge of rainwater. Unregulated exploitation of groundwater for irrigation, industrial and domestic use had resulted in the water table going down to 250 m. In summer water had to be brought to the city in trains.

To address the problem, the Bhoojal Samvardhan Mission, Dewas was launched in 1999 with the active participation of the citizens. Tubewell drilling was banned and rainwater harvesting was made mandatory for all houses using tubewells.

The citizens contributed labour and money for rainwater harvesting projects. A number of rooftop water harvesting systems were constructed, ponds and percolation pits dug, and the existing ponds and wells deepened.

With help from the Central Ground Water Board, the district engineers developed a low-cost filter, and used it to filter rooftop harvested water to recharge dry wells. More than 1,000 such filters were distributed to citizens. These filters were subsequently called the 'Dewas filter'. To recharge deep aquifers, the administration also developed other techniques and structures such as sub-surface dams and boulder dams.[1]

DELHI

What you need to know

- RWH structures are compulsory for all new buildings: private residences, group-housing, multi-storeyed, government, quasi-government buildings on plot size of 100 sq m and above.
- Building plans will not be approved if RWH is not incorporated in plans.
- Water and sewage connections will not be given if RWH systems are not constructed.
- Delhi Jal Board (DJB) provides a grant of Rs 100,000 or 50 per cent of the cost of constructing RWH schemes to resident welfare associations (RWAs), cooperative group housing societies, schools, colleges, hospitals and other institutions. Those who avail of this grant will have to sign a contract for maintenance of the system and submit a half yearly report on the same. Non-compliance will attract a penalty.
- The New Delhi Municipal Council (NDMC) has been giving a rebate on property tax from the financial year 2008-09, applicable for the next four years. Under this scheme, the NDMC will provide a rebate of 10 per cent of the property tax on 20 per cent of the cost of installing an RWH system, whichever is lower. This is valid for those who have constructed a RWH system.
- RWH schemes can be taken up with funds available with area MLAs, and the 'My Delhi-I Care Fund' made available to the deputy commissioner (revenue) by the Delhi government.
- To encourage RWH, the Delhi Jal Board instituted the Chief Minister's Best Rain Harvesters' Award in 2006. First and second prizes are given for institutional (Rs 2 lakh, 1 lakh) and individual (Rs 1 lakh and Rs 50,000) categories together with a plaque and citation. The first set of awards was given away by the chief minister in 2007.

Who can help you

- Delhi Jal Board has a rainwater harvesting (RWH) cell

For drawings and technical details:

- http://www.delhi.gov.in/wps/wcm/connect/DOIT_DJB/djb/home/rain+water+harvesting/

For details of DJB grant for RWH constructions, please look at:

- http://www.delhi.gov.in/wps/wcm/connect/doit_djb/DJB/Home/Rain+Water+Harvesting/

For FAQs:

- http://delhi.gov.in/wps/wcm/connect/doit_djb/DJB/Home/Rain+Water+Harvesting

POLICY RECOMMENDATIONS

While city municipalities have taken path-breaking measures, citizens and government have to be encouraged to take ownership of the RWH process, making it "everybody's business". Legislation by itself will not translate into ground-level action, unless accompanied by effective pricing incentives and disincentives. Thus far, the incentives for undertaking RWH have been meagre and also tied up in red tape, which deters common citizens from making the effort to take advantage of them. At the same time, municipal water is supplied at extremely low cost. There is no motiviation for citizens to take up RWH or recycle their wastewater. They continue to use water wastefully. Not a single city has any rule or a disincentive that will discourage wasteful use of water.

Recommended policy measures:

- Promulgate a law to prevent further encroachment or conversion of water bodies into land;
- Bring in legal measures to protect catchments for drinking water and rivers;
- Degraded lakes need to be regenerated on a priority basis;
- Costs of sourcing, conveyance, treatment and collection and treatment of wastewater should be incorporated in the price of water supplied;
- Sewage could be recycled and reused for horticulture or industrial purposes;
- Laws or financial disincentives need to be put in place to discourage wastage of water;
- Focus on implementing RWH in all public buildings, large public areas such as parks;
- Capture stormwater for recharge or treatment and storage.

2

SECTION

How to plan and design an RWH system

Historians have described India as a 'hydraulic' civilisation, one that was well versed in making use of its water endowment effectively and efficiently. Even a thousand years ago, India's urban settlements ensured a sustainable water supply from rivers, tanks or lakes. In modern India, if every city were to ensure that every drop of rain that fell on it would be captured, stored or recharged to the aquifer, cities will not need to take water from far-off sources.

There are diverse ways in which rainwater can be captured in cities, from micro-catchments of rooftops to macro-catchments of urban lakes. Rooftop water harvesting provides an affordable means of accessing good quality water at the point of consumption. Households can capture water falling on their roofs to supplement existing water supply and reduce their dependence on municipal supply.

Municipalities can take responsibility to revive or develop large water bodies to capture rainwater and recharge groundwater – this will also serve to regulate floods. Run-off from roads and other public spaces can be collected to recharge the aquifer.

The following pages show how every urban citizen can capture the rainwater endowment. They take you step by step, from planning to building the system and maintaining the structure. They tell you how the type and size of the RWH structure is determined by precipitation, catchment area, physical topography, nature of aquifer and soil. They show how simple rainwater harvesting systems can be built at very low costs to yield good results.

2

SECTION

How to plan and design an RWH system

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- To ensure a cost-effective rainwater harvesting (RWH) system, a plan has to be put in place which would incorporate collection of information, a study of the site plan, estimation of the water harvesting potential and allocation of funds

- Users are motivated to invest in RWH when they save on costs, and especially when there is no municipal supply

- Correct estimation of size of storage tanks is important as it is the most expensive part of the system. Sizing can be determined based on demand or availability of rainwater

- Storage tanks can be placed both overground and underground and made of various material comprising cast-iron sheets and poly-vinyl chloride

- In 1999, CSE built a simple RWH system, consisting of recharge pits with bores, a trench, a recharge well converted from an old storage tank and a defunct borewell used to recharge water from roof areas

- A number of in-built filter mechanisms within an RWH system ensure clean rainwater: an example is the first flush which allows the first spell of rain with dissolved impurities to flow away

- Water from a clean roof catchment is nearly of potable standard. Keeping the roof clean is the most cost-effective way of collecting quality rainwater

- Harvested rainwater can be further purified by boiling, cholorination, direct solar radiation and ultra-violet rays

04

Planning and designing

You may have some basic questions that you need to clarify before understanding a rainwater harvesting system. Finding answers at the planning stage is vital – it will ensure that the structure is effective, economical and sustainable. One of the first facts to judge – how much water is available for harvesting? Is the rainwater to be collected for direct use? Or, is it to be recharged into the aquifer?

If you are to store water, you would need to plan the numbers, capacity of storage structures, the kind of material to be used, and the site. When recharging groundwater, you will need to know the number and type of recharge structures to be built, the correct siting and finally, the ways to ensure water quality, whether through filtration or any other means.

Above all, you need to know whether the structures are cost-effective, and whether you can afford the cost of construction.

The planning and designing of an RWH system is a step-by-step process. A checklist:

- **Step 1:** Collection of information on the catchment, rainfall, physiography, soil and rock, aquifer, water demand, objectives and uses, laws and incentives.
- **Step 2:** Studying the site plan to understand the slope, the location of the catchments, space available and other details.
- **Step 3:** Estimating the amount of water that can be collected (water harvesting potential) and matching this with the water demand.
- **Step 4:** Deciding the number, type, capacity and location of structures – whether to harvest water for direct use from storage containers or to recharge the aquifer.
- **Step 5:** Allocating funds – the budget is one of the most important determinants of rainwater harvesting work.

COLLECTION OF INFORMATION

CATCHMENTS: TYPES, AREA AND LOCATION

From the site plan or from actual measurements, find out:

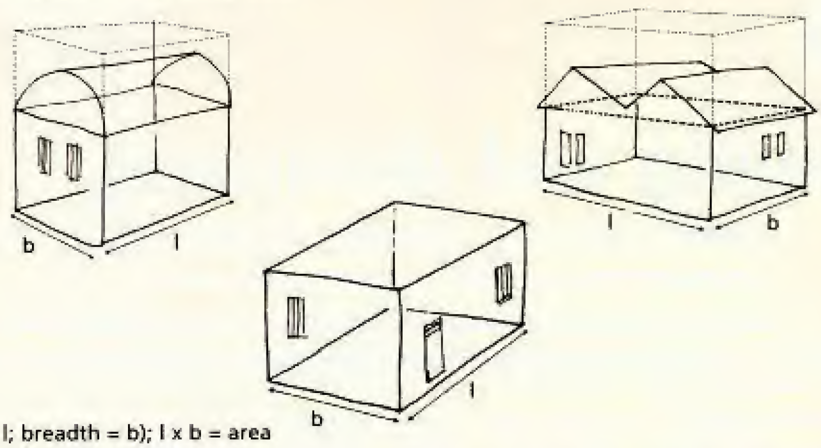
- Types of catchments – roof or paved, unpaved.
- Number of catchments.
- Dimensions of catchments.
- Location of catchments.

When calculating the catchment area:

- Note down area of each catchment from site plan.
- In the absence of a site plan, measure each area and create a site plan that provides details of catchments with the dimensions.

  [Area of catchment (C) = length (l) x breadth (b)]
- Regardless of the shape of the roof, the catchment area would be the area equivalent to the area under the rooftop. If the total available roof area comprises of more than one roof, then the dimensions of each roof can be noted down and added to arrive at the total area (see Figure 4.1: *Calculation of the rooftop area*).

Figure 4.1: Calculation of the rooftop area



(length = l; breadth = b); l x b = area

- For irregular dimensions of ground level catchments such as a winding driveway, break it into measurable shapes such as rectangles or triangles and measure.

COLLECTION EFFICIENCY AND RUN-OFF COEFFICIENT

Collection efficiency: Not all the rain that falls on the catchments is available for rainwater harvesting. Some of the water that falls on catchments may be lost because of evaporation, seepage into the ground, absorption by roof materials, improper fittings, leakages from pipes and gutters and clogging in various parts of the system. These factors and the effective catchment area largely influence the collection efficiency.

Run-off coefficient: This is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface. More water runs off smooth and impervious surfaces such as roofs or paved areas than soils and unpaved areas. Different catchment materials absorb water to differing extents.

(See Annexure 1 for information on run-off coefficients of different types of catchment).

RAINFALL

There are four kinds of information on rainfall that you need to gather:
- *Annual average rainfall* gives an overall picture of the total amount of water that can be collected.
- The *pattern of rainfall over different months* indicates when rainfall is available – whether most of the year or only during a certain part of the year.
- The *number of rainy days* indicates whether it is better to store rainwater or to recharge it. If most of the rain falls only for a short span of time, then it is better to recharge the aquifer.
- The *peak rainfall intensity* determines the size of the storage or recharge structure. The size is calculated on the basis of the amount of water needed to be stored or recharged during the most intense spell of rain, which can range from fifteen to thirty minutes. Recharge structures will have to be designed in such a way that they will be able to deliver the peak intensity rainfall to the aquifer or store it temporarily during such intense spells.

(See Annexure 1 for annual average rainfall, number of rainy days and rainfall intensities).

Where to get rainfall data
- The local meteorological station; the website of the Indian Meteorological Organisation. [http://www.imd.gov.in/doc/climateimp.pdf (for climatological data of important cities)].
- The revenue department which compiles such information at district level. Some cities have put up city-level rainfall data on their website.

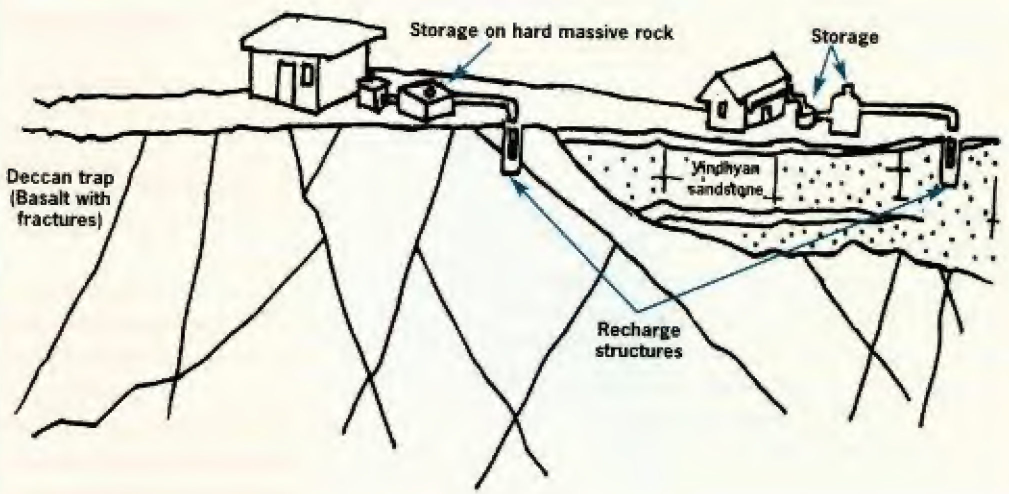
GEOLOGICAL AND HYDRO-GEOLOGICAL DATA

For systems where the harvested rainwater is used to recharge the aquifer, selection of the correct site is important. Information must be collected before locating the site:

- **Soil:** Will the soil type allow water to percolate easily? For an answer to this, you have to know the soil type – whether it is sand, gravel, silt, loam or clay.
- **Rock:** Note down the type of rock – massive, fractured, fissured, weathered or sedimentary.
- **Physiography:** Note whether the area is hilly, plains, coastal or desert.
- **Aquifer:** Find out depth of water level, thickness and nature of aquifer – confined, unconfined (*see Annexure 3 for definitions*).

Selecting the right site: storage and recharge in Bhopal's Deccan trap

As can be seen from the geological cross-section, there are two types of rock formations: (i) Deccan trap basalt with fractures, (ii) sedimentary Vindhyan sandstone. In areas underlain with massive rock and clayey soil, recharge is not an option. Recharge can be effective where there are fractures. In the sedimentary portions, both storage and recharge can be done.



The aquifer must lie at least 8-10 metres below ground level (m bgl), never at a shallow depth. It should be unconfined – exposed and recharged directly from the surface. It must also have good hydraulic conductivity as well as transmissivity so that when water is recharged quickly, it spreads horizontally to prevent a water mound forming below the surface.

Recharge is more effective when the saturated zone – where all available spaces are filled with water – has substantial depth.

How to get geological data

- Inquire with the local people, contact the local drilling agencies.
- Gather litho logs/borehole strata chart of the existing tubewells on the site to identify types of soil and thickness of soil layers.
- Literature survey – reports of irrigation departments, central/state groundwater boards, Geological Survey of India, Soil Survey of India.

WATER DEMAND

The size of the RWH structure is determined by two factors – how much water is needed and how much is available. The following factors may be considered:

- *The total water currently used*: This indicates the total water demand and the portion of the total water needs that can be met from rainwater harvesting.
- *The per capita water demand*: In case you cannot find out the exact amount of water used, you can find out the number of persons accessing the water and multiply this with the per capita norm for water supply to arrive at the total water demand. This would be the method used for urban water supply planning purposes.
- *The water demand during the driest period*: This is an estimate of the essential quantum of water needs during the driest period so that plans can be made for water harvesting to meet this minimum need.

So, how to get information on water demand?

- *Monitor usage of water from the overhead water tank*: Eg. If the tank has a capacity of 1,000 litres and this is filled up once a day, then the annual water demand is 365,000 litres of water.
- *Municipal water supply bills can provide an estimate of total water supplied.*
- *Estimate the amount of water pumped from a borewell*: If you know the yield of the borewell and measure the number of hours of pumping, it will give you the total water pumped out.
- *Finding out the number of times water is purchased from tankers and the quantum of water supplied.*
- *Undertake a water audit and measure the amount of use through different fixtures.*

OBJECTIVES AND USES

It is important to know for yourself how you want to use the rainwater. Once you know that, you will know the level at which the water should be treated. Different uses will require different levels of water quality. So, you need to examine the pattern of water use, and its source of supply. For instance, find out the source of supply for drinking and cooking, gardening and any other purposes. Then you need to determine which portion of this you want to replace with rainwater. You may want to use harvested rainwater to supplement your municipal supply and therefore use it for gardening or toilet flushing. Or you may want to use it as the sole source of water supply. In this case, adequate treatment capacities must be put in place to remove biological, physical and chemical impurities. If there is no municipal water supply and you are purchasing water from tankers, then the objective may be to recharge the aquifer or store the water so that you can reduce your dependence on tanker supply and bring down the water bill.

LEGISLATION AND INCENTIVES

Many state governments and city municipalities have passed laws that make it mandatory for existing or new buildings to have RWH systems. You must be abreast of these laws in order to make sure that you are compliant on all counts. There are also many incentives for people who take up rainwater harvesting and you could find out if they are applicable in your city.

(See Chapter 3, Section 1, for more details on legislation and incentives)

STUDYING THE SITE AND THE ROOFTOP PLAN

To begin with, you need to have a detailed map of the site and the rooftop.

- A study of the site plan will indicate the space available for water harvesting structures. This will determine the size and location of the structures.
- Note the number and location of existing rainwater pipes, outlets/spouts in the building.
- Identify if there are any defunct or existing borewells, a swimming pool or water storage

Figure 4.2 (a): Standard site plan (before RWH)

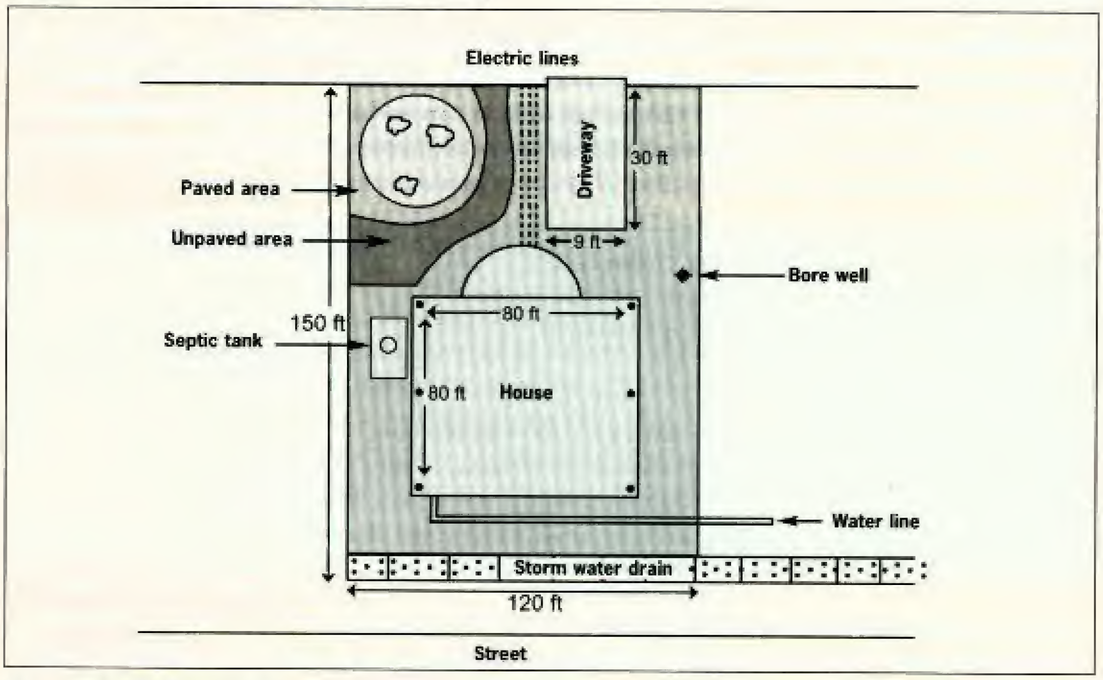
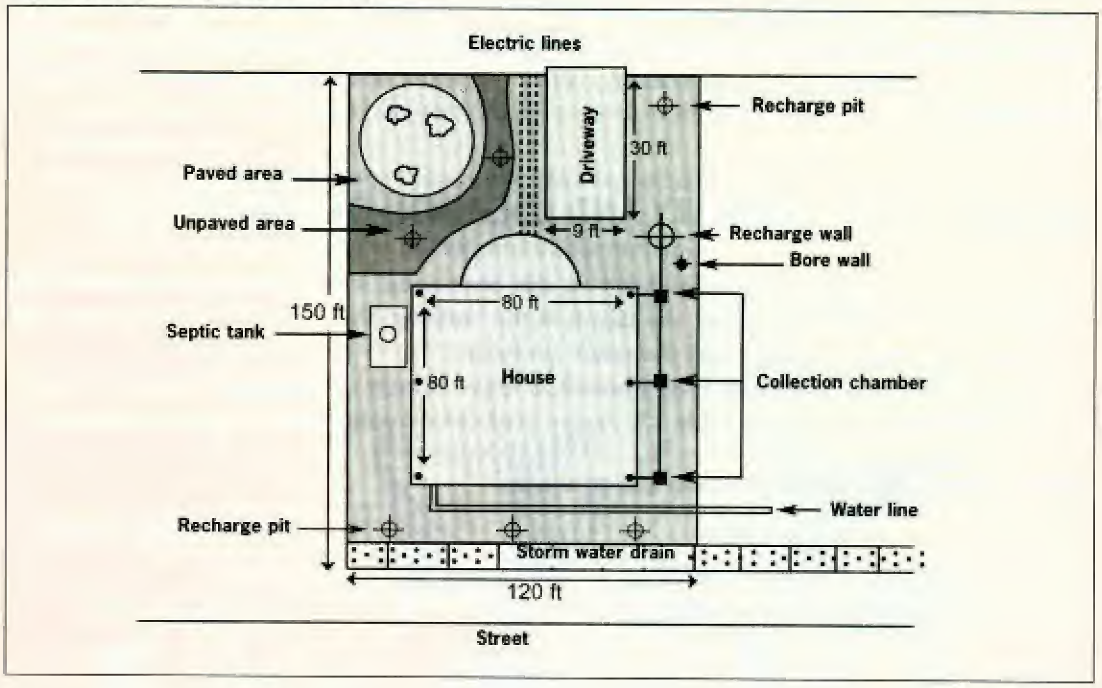


Figure 4.2 (b): Site plan (after RWH)



tanks that can be used for storing the harvested water. Mark all the open spaces in the colony from where water can be harvested as well as stored.

- Determine the natural drainage, slope and location of stormwater drains. This will help laying out the conveyance pipes along the natural drainage patterns. This is particularly important while planning for a large complex or colony.
- Mark the location of plumbing (water and sewage) and electrical lines on site. Care must be taken to circumvent the plumbing and electrical lines while constructing the RWH structures. In case of a project in public places it becomes even more important to see that the underground sewer, water supply and other such cables and lines are not inadvertently damaged.
- Note that space is set aside for a generator room, compost pit and waste dump.
- The RWH structures should be as close as possible to the source and use of water.

WATER HARVESTING POTENTIAL

As a thumb rule, if you have 10 mm of rainfall over 100 sq m of roof area you will get 1,000 litres of water (volume = rainfall x area). However, there is some loss due to evaporation or absorption by catchment surfaces. The actual volume can be ascertained by determining the run-off coefficient of the catchment which indicates the proportion of rainwater that can be harvested from the total rainfall (see Box: *How much rainwater can be collected?*).

How much rainwater can be collected?

Total volume of water = area x run-off coefficient x rainfall

Area = length x breadth = 20 m x 10 m = 200 sq m

Run-off coefficient of roof = 0.8

Annual rainfall = 500 mm

(1) Rainwater harvesting potential = 200 x 0.8 x 500 = 80,000 litres

(2) Water demand, family of four, consuming 540 litres/day = 540 x 365 =197,100 litres/year

(3) Water demand, family of four, the three driest months = 540 x 90 = 48,600 litres

(4) Water demand for toilet flushing and gardening (yearly) at 180 litres/day = 180 x 365 = 65,700 litres

If you want to arrive at the RWH potential more accurately, you can record daily or weekly rainfall data. Once you have an idea of how much water can be harvested, match this against your water demand. This way, you can determine the size of the system as well as the level of water treatment required, taking into consideration the budget. If it is not practical to meet all water needs for the entire year from rainwater harvesting, then the water demand for the driest period or the period of acute water scarcity can be estimated so as to use rainwater to mitigate water scarcity.

NUMBER, TYPE, CAPACITY AND LOCATION OF STRUCTURES

- *Number of structures*: This will depend on site conditions, which include the position and location of the down-take pipes, the layout of the building, the size of the storage tank, the slope of the roof, the budget and the space available.
- *Type of structures*: The decision on whether to make storage or recharge structures depend on a number of factors (see Table 4.1: *Hydro-geological conditions and type of structure*).

Table 4.1: Hydro-geological conditions and type of structure

Parameter	Type/condition	Recommended structure
Nature of aquifer	Impermeable, non-porous, non-homogeneous, hard rock area	Storage
Depth of groundwater table	More than 8 metres	Recharge and storage
Nature of terrain	Hilly, rocky or undulating	Storage
	Uniform or flat, alluvial and sedimentary	Recharge and storage
Nature of soil	Alluvial, sandy, loamy soils, gravel, silty, with boulders or small stones (*kankar*)	Recharge and storage
	Clayey soil	Storage
Nature of geological formation	Massive rocks (such as the Deccan trap)	Storage
	Fractured, faulted or folded rocks, or comprises of weathered, jointed or fissured rocks	Recharge and storage
Nature of rainfall and monsoon	Number of rainy days are more, bi-modal monsoon, not intensive, uniformly distributed	Storage
	Uni-modal monsoon, rainfall available only for a few months	Recharge and storage

- *Capacity of storage tanks*: This will depend on the type of monsoon, bi-modal or uni-modal, number of rainy days, total demand and the rainfall intensity. If the rainy days are more, a smaller tank is sufficient as the tank can get frequently filled. The size also depends on the demand and the total rainfall. Where the rainfall intensity is greater, the size will increase.
- *Location of structures*: The location of structures will depend on the layout, the slope, the presence of other services and pipes and proximity to point of use.

ALLOCATING FUNDS

The budget available for a rainwater harvesting project is one of the most important determinants of the type, size and number of structures that can be set up. In large projects, where there is a possibility of budgetary constraints, it is better to design the project in phases. The cost of an RWH system will depend on a number of factors:

- *Catchments*: The cost on storage or recharge structures will depend on type of catchments and area, which will determine the amount of water harvested and therefore the size of the structures.
- *Drainage pattern*: The cost on the conveyance systems will depend on the flow direction, spreading of rainwater pipes and flow of stormwater drains.
- *Retrofitting/new construction*: Retrofitting on existing buildings will cost more than new constructions.
- *Geology, hydro-geology and meteorological parameters*: Recharge structures in hard rock terrain will cost more and areas of high intensity rainfall will require larger storage.
- *Purpose of harvesting*: Treatment systems will increase cost and therefore the use of the rainwater will determine cost.
- *Availability of unused tanks*: Availability of unused or dry/abandoned tube wells/open wells will reduce cost.
- *Material used*: The cost of the system will also depend on the materials used.

(See Annexure 2 for a form on documenting information)

CASE STUDY

AUTOCOMPS CORPORATION PANSE PVT LTD, MOSHI, PUNE

Planning the steps for rainwater harvesting

A sustainable water management system has been meticulously planned and implemented at Autocomps Corporation Panse Pvt Lt at Moshi on the outskirts of Pune, a manufacturer of automobile press components and assemblies. The planning, designing and construction of the rainwater harvesting system was undertaken by Comprehensive Water Management Solutions Pvt Ltd, Pune. The architect involved was inspired to branch off into water management after learning about rainwater harvesting.

The factory is not connected to the municipal supply and groundwater was the only source of water. There are 150 people working in the factory the year round. The hard rock terrain made the availability of groundwater very difficult. The water was sourced from two borewells and one of these had gone dry. The factory decided to build an RWH system in order to recharge the groundwater and also to store it for use.

PLANNING AND DESIGNING PROCESS

Information collection

A detailed planning process was undertaken that included information collection on rainfall, geology, soil and water demand (see Table 4.2: *Detailed parameters*).

Table 4.2: Detailed parameters

Total plot area	12,000 sq m
Area of roof of sheds (2)	2,400 x 2 = 4,800 sq m
Paved and unpaved areas	7,000 sq m
Rainfall coefficient for rooftop	0.85
Rainfall coefficient for unpaved areas	0.5
Average rainfall of Pune assumed	600 mm
Hydro-geology of site	Black cotton soil up to 1 m depth and hard basaltic rock
Topography	Sloping with incline of 3 m from south-west to north-east
Water sources	1 borewell yielding 15,000 litres a day

Source: Comprehensive Water Management Solutions, Pune

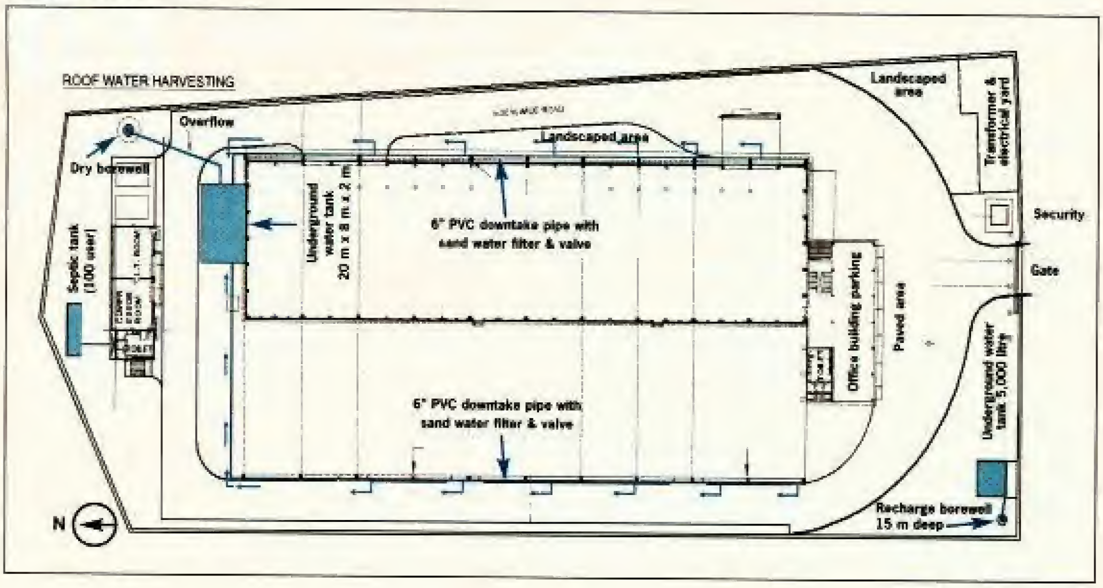
A. Water demand was calculated on the following basis:
   No of persons = 500
   No of working days = 300

Table 4.3: Calculating water demand

Type of use	Unit requirement (litres)	Water quantity per day (litres)	Water quantity per year (cu m) (1,000 litres = 1 cu m)
Drinking	2/person/day	1,000	300
Hand wash	10/person/day	5,000	1,500
Sanitation	30/person/day	15,000	4,500
Water for industrial processing	2,000/day	2,000	600
Water for landscaping	10,000/day	10,000	3,000
Total		**33,000**	**9,900**

Source: Comprehensive Water Management Solutions, Pune

Figure 4.4: Site plan



B. *Rainwater harvesting potential*

Water harvesting potential = Catchment area x annual average rainfall x run-off coefficient
Rooftop: 4,800 x 600 x 0.85 = 2,448,000 litres
Paved and unpaved areas: 7,000 x 600 x 0.5 = 2,100,000 litres

Total RWH potential = 4,548,000 litres or 4,548 cu m

C. *Calculating demand-supply gap*

Total water demand (before rainwater harvesting): 33,000 litres/day
Borewell yield: 15,000 litres/day

Gap: (total water demand – yield) = (33,000 – 15,000 litres/day) = 18,000 litres/day
[The gap had to be plugged by water tankers as there was no municipal water supply
Two tankers of 10,000 litres capacity = 2 x Rs 500 = Rs 1,000/day
For 300 working days = Rs 300,000/year]

D. *Plan for RWH to eliminate water supply costs*

Total demand = 9,900 cu m/year
Total RWH potential: 4,548 cu m/year
Total from groundwater: 15,000 litres/day x 300 days = 4,500 cu m/year
Potential water availability after RWH: 9,048 cu m/year

Gap: 9,900-9,048 = 852 cu m
[Gap to be met by using recycled sewage water]
Water used by 500 persons @ 40 lpcd (handwash + sanitation) = 500 x 40 x 300 = 6,000 cu m
Sewage generated = 80 per cent of intake = 6,000 x 80 per cent = 4,800 cu m

Gap = 852 cu m; therefore, the demand gap will be met with the 4,800 cu m of available recycled water.

The decisions taken were as follows:

- Rainwater from the roof would be harvested and stored in an underground tank to be used only for drinking purposes.
- Rainwater from paved and unpaved areas would be harvested and recharged to the aquifer. This will be pumped out and used for toilets, processing and other uses.
- Water used for toilets and handwashing would be recycled and reused for gardening.

Table 4.4: Source and usage chart

Type of use	Annual demand (cu m)	Source	Annual availability (cu m)	Tank capacity (cu m)	Remarks
Drinking	300	Rooftop harvesting	1,440	320 (20 m x 8 m x 2 m)	Overflow of tank used for recharge borewell in north-east corner
Sanitation, handwash and processing	6,600	Paved and unpaved area water harvesting recharged and groundwater used	Harvested = 2,100 Groundwater = 4,500	5,000 litres	Originally only one borewell would yield 4,500 cu m/year. Groundwater level increased and both wells have water. The working tubewell has doubled yield to 9,000 cu m. Dry well yields 3,000 cu m
Landscaping	3,000	Recycled water	4,800		

Source: Comprehensive Water Management Solutions, Pune

Treatment for use

A. *Rooftop harvested water for drinking*
All 20 downtake pipes are equipped with water filters and first flush and collected in underground tank. Water for drinking is used after going through RO filter at two drinking 'water points' in the factory.

B. *Groundwater used for handwash and sanitation*
Stormwater used for groundwater recharge is desilted and recharged through filtration materials. Groundwater in the location is hard. A softening plant of (25,000 litre capacity) was installed to soften the water before use.

C. *Recycled water for landscaping*
A decentralised wastewater treatment plant was installed, where sewage water is treated and used for garden irrigation.

Designed and implemented by
Comprehensive Water Management Solutions Pvt Ltd (CWMS), Pune 411 004

05

Preparing your budget

The implementation of a rainwater harvesting (RWH) system, be it large or small, for a house or for a colony, will depend solely on the availability of funds. Therefore, the plan has to be cost-efficient, affordable and scalable. The major constitutents of a RWH system, rain and catchment area come free of cost, being nature's bounty. The availability of existing structures like borewells, dugwells and tanks greatly reduce costs. When the RWH system is incorporated at the construction stage, the costs are lower than when a retrofitment has to be carried out. The use of water also determines the cost – high quality use, such as for drinking purposes will need greater investments in water treatment.

Preparing an accurate cost estimate for a proposed RWH system is one of the key factors in ensuring implementation in an efficient and cost-effective manner. A number of factors affect the cost of a RWH system (see Table 5.1: *Parameters that affect the cost of a RWH system*).

Table 5.1: Parameters that affect the cost of a RWH system

Part of system	Parameter	How it affects cost
Entire system	Retrofit	Retrofit will cost more than incorporating the system during construction
Catchment	Size	Larger the catchment area, greater the cost
Interconnecting pipes	Distance to storage/ recharge	If rainwater outlets are not easily accessible to the storage tank or recharge structure, length of interconnecting pipes will increase the cost
	Drainage slope	If the drainage slope is well directed, water can be brought to the storage area without much effort or cost
Recharge systems	Geology and terrain	Hard rock will require greater drilling effort and will cost more
	Unused borewells and dugwells	Availability of dry and unused bore wells can be used for recharge, saving on cost of drilling
Storage systems	Unused storage tanks	Will save on cost of constructing storage tanks
Filter and treatment systems	Use of rainwater	When water is used for potable purposes, greater filtration and treatment is required and is thus costlier

THE COST COMPONENTS

The following components of an RWH system has to be budgeted for:

- Inter-connecting pipes
- Gutter
- First flush systems
- Filters
- Overhead storage tanks (ready-made)
- Overhead storage tanks – construction costs
- Cost of constructing collection chambers, sedimentation tanks, underground storage tanks, recharge wells, trenches or pits
- Maintenance and repair costs (filter materials replacement)
- Treatment system

Reuse, innovate and cut costs

Mussoorie, like all tourist hill stations faces acute water scarcity in the summer. In order to save on municipal supply, a rainwater harvesting (RWH) system was built at the Hotel Padmini Niwas by Harshada Worah, its owner. The hotel, which comprises one main building and two annexes, caters to about 75 guests per day during the peak season and has a permanent staff of 25.

In the hill areas, it is not easy to construct underground storage systems as permission is needed for any kind of excavation. Thus, existing structures in the hotel, such as water heaters from the British period were converted into RWH storage tanks. Two tanks of capacity 750 litres were connected to the main building, and supply the toilets for the staff.

In the next phase, the sewage tank within the premises was cleaned and repaired and converted into an underground storage tank, of capacity 25,000 litres. It stores rainwater collected from the rooftop of the second annexe of the building. The water from this tank is used for gardening.

Two smaller tanks of 1,000 and 500 litres were added later and connected to the rooftop of the main building.

Apart from this, the rooftops of the third annexe and the orchid house are connected to collection tanks of capacity 500 litres and 1,000 litres respectively. The run-off from the undulating topography of the site near the orchid house is collected in another 6,000 litres capacity tank. These three tanks store water just for gardening. A total storage capacity of 35,500 litres was created. The total cost of the system was just Rs 10,000 in the year 1988.

SUSHMITA SENGUPTA / CSE

Water heater converted to RWH tank

SUSHMITA SENGUPTA / CSE

Sewage tank converted into underground storage tank

Inter-connecting pipes and gutters: The most important determinant of conveyance costs is the length of the pipes. A system must be so designed that the length of the pipes are reduced to the extent possible, depending on the site conditions and space available.

The second important factor is the material used to manufacture the pipes. While deciding on the material, the wear and tear and durability must be taken into consideration. Pipes come in standard lengths of 3 m or 6 m and the diameter is of 4, 6 or 8 inches, depending on the catchment area. In addition to the cost of pipes, there will be supplementary materials such as elbows, brackets and straps that have to be factored in.

Gutters form a part of the conveyance system in case of sloping roofs. Locally available materials like plain galvanised iron sheet, PVC pipes and bamboo can be folded to form semi-circular or rectangular gutters (see Table 5.2: *Costs of commonly used conveyance materials*).

Table 5.2: Costs of commonly used conveyance materials

Material	Unit of cost	Cost in Rs
MS (mild steel) pipes (4" dia)	metre	400
MS pipes (6" dia)	metre	600
PVC (poly vinyl chloride) pipes (6 kg/sq cm) (4" dia)	metre	Medium - 30; Heavy - 39
PVC pipes (6 kg/sq cm) (6" dia)	metre	Medium - 70; Heavy - 90
Gutters	metre	600
Socket 4 inches	each	35
Socket 6 inches	each	110
T-bend 4 inches	each	60
T-bend 6 inches	each	250
Bend 4 inches	each	50
Bend 6 inches	each	150
Door bend 4 inches	each	70
Door bend 6 inches	each	250
End cap 4 inches	each	30
End cap 6 inches	each	60

Source: Survey of hardware shops in Delhi undertaken by CSE in 2011

First flush systems and filters: These range from a simple extension of the downtake pipe which is closed with a valve to complicated systems regulated by volume or flow-rate. In India, generally very simple systems are used. The complexity of the filters used depends on the end use of the harvested water. Filters range from relatively simple and inexpensive sand filters that have been developed by users to those made of ceramic or steel mesh and are sold as ready-made filters (see Table 5.3: *Costs of some commonly available filters*).

Table 5.3: Costs of some commonly available filters

Filter	Cost (Rs)	Cost quote by
Rainy filters	6,000 – 21,000	Farmland Rainwater Harvesting Systems
Varun filter in 60-90 litre drum	2,500 – 4,500	Rainwater Club
Vinayak filter (6 inches dia filter)	1,500	Vinayak Water Solutions
Amber filter (6 inches dia filter)	6,500	AMBER, Bhopal
Pop-up filter	3,990	Raj Iritech (P) Ltd
Sand filter in 60 litre drum	1,500 – 2,000	CSE

Source: Respective manufacturers of the filter

Overhead storage tanks: The cost of an over the ground storage tank will vary with the material of the tank. A range of materials can be used depending on the affordability of the users – simple recycled steel drums to PVC or HDPE (high-density polyethylene) tanks, from ferrocement tanks to RCC tanks. The second most important cost determinant will be the size of the tank (see Table 5.4: *Some typical costs of storage tanks*).

Table 5.4: Some typical costs of storage tanks

Material	Cost per litre (Rs)
Brick masonry*	3.50
PVC (poly vinyl chloride) tanks	Light – 2.30 ; Heavy – 3.20, 4.20, 4.80
Sheetal brand tanks	3.80
Sintex brand tanks	4.00
Ganga brand tanks	2.80
Hindal brand tanks	2.20
SPL brand tanks	2.20
Ferro-cement	2.50
RCC (roller-compacted concrete)	8.00

Source: Survey of hardware shops in Delhi undertaken by CSE in 2011; * Brick masonry quotation by Delhi based contractors

Water treatment: Water treatment systems are usually used when water is used for drinking purposes. Water treatment systems range from simple disinfectants such as chlorine, alum to reverse osmosis systems. There are a number of branded products available in the market (see Table 5.5: *Some typical costs of water purifiers*).

Table 5.5: Some typical costs of water purifiers

Technology	Price range (Rs)
Ceramic candles	150-1,200
Iodised resin	Around 300
Ultraviolet	4,000-9,500
Reverse osmosis	10,000-18,000
Cartridge	1,500-1,600

Source: Survey of hardware shops in Delhi undertaken by CSE in 2011

Recharge structures and underground storage tanks: The cost of building recharge structures will vary widely from place to place depending on the local rates for labour, materials and transport. Two kinds of cost estimates are provided here. The first lists costs for a system consisting of an underground sump, recharge pit, filter tank and overhead tanks from the residence of N Arunachalam, Madurai, 2006 (see Table 5.6: *Cost of setting up an RWH structure, Madurai*). An expected cost structure of a recharge structure or underground tank, based on a survey of hardware shops in the national capital of Delhi is also provided (see Table 5.7: *Expected costs for RWH components, Delhi*).

Table 5.6: Cost of setting up an RWH structure, Madurai

Part of rainwater harvesting system	Dimensions	Total cost (Rs)
Underground storage tank	3.66 m x 1.22 m x 2.44 m = 10.895 m^3	17,860
Filter tank	3.35 m x 1.1 m x 2.44 m = 8.995 m^3	14,740
Filter media		3,000
PVC tank (3)	10,000 litres	7,500
Pipes		1,000
Total		**44,100**

Source: M Arunachalam, Madurai

Table 5.7: Expected costs for RWH components, Delhi

Item	Unit	Rate (Rs)
Excavation in all kinds of soil	cu m	150
Excavation in hard rocks	cu m	350
PCC foundation	cu m	3,200
Brick work	cu m	3,000
Half brick work	sq m	4,200
Plaster	sq m	120
RCC (roller-compacted concrete)	cu m	9,500
Drilling 4 inches dia recharge bore in soil using hand auger	metre	230
Drilling 6 inches dia recharge bore in soil using hand auger	metre	300
Drilling 4 inches dia recharge bore in hard rock using mechanical drill	metre	700
Drilling 6 inches dia recharge bore in hard rock using mechanical drill	metre	800
Collection chamber 30 x 30 x 30 cm	each	800
Collection chamber 45 x 45 x 45 cm	each	1,500
Collection chamber 60 x 60 x 75 cm	each	2,500
PVC (poly vinyl chloride) slotted pipe	4 inches	300
PVC slotted pipe	6 inches	450
Air vent/covel 4 inches	each	20
Air vent/covel 6 inches	each	50
Metal grill cover	kg	50
Welded wire mesh	kg	50
Chicken wire mesh	sq feet	3

Source: Civil works cost provided by Delhi contractors; costs of readymade hardware material from a survey of hardware shops in Delhi in 2011

ECONOMIC BENEFITS

Rainwater harvesting systems provide additional and quality water. Yet people are often reluctant to invest in a system when they get assured municipal water supply since its is supplied at highly subsidised rates.

The motivation to invest in a RWH system comes only when:

- Municipal water supply is erratic or insufficient;
- Municipal water is of poor quality;
- Municipal water supply is expensive, say, for industries;
- Specifically when municipal water supply does not exist

How can the economic benefits from rainwater harvesting systems be quantified?

To take an example, it can be calculated by adding up the savings derived from spending on water tanker supply and / or the municipal water bill.

- Expense for constructing a rainwater harvesting systems = Rs 3 lakh
- Annual expense for purchase of water from tankers = Rs 60,000
- Annual expense for municipal water supply = Rs 24,000
- Total annual water bill = Rs 84,000

Tanker water supply was stopped after rainwater harvesting system began to yield water.

- Annual savings in water bill = Rs 60,000
- Number of years taken to recover cost of investment = 300,000/60,000 = 5 years
- Payback period to recover investment = 5 years

CASE STUDY

PAYBACK ANALYSIS OF CYGNUS MICROSYSTEMS, HYDERABAD

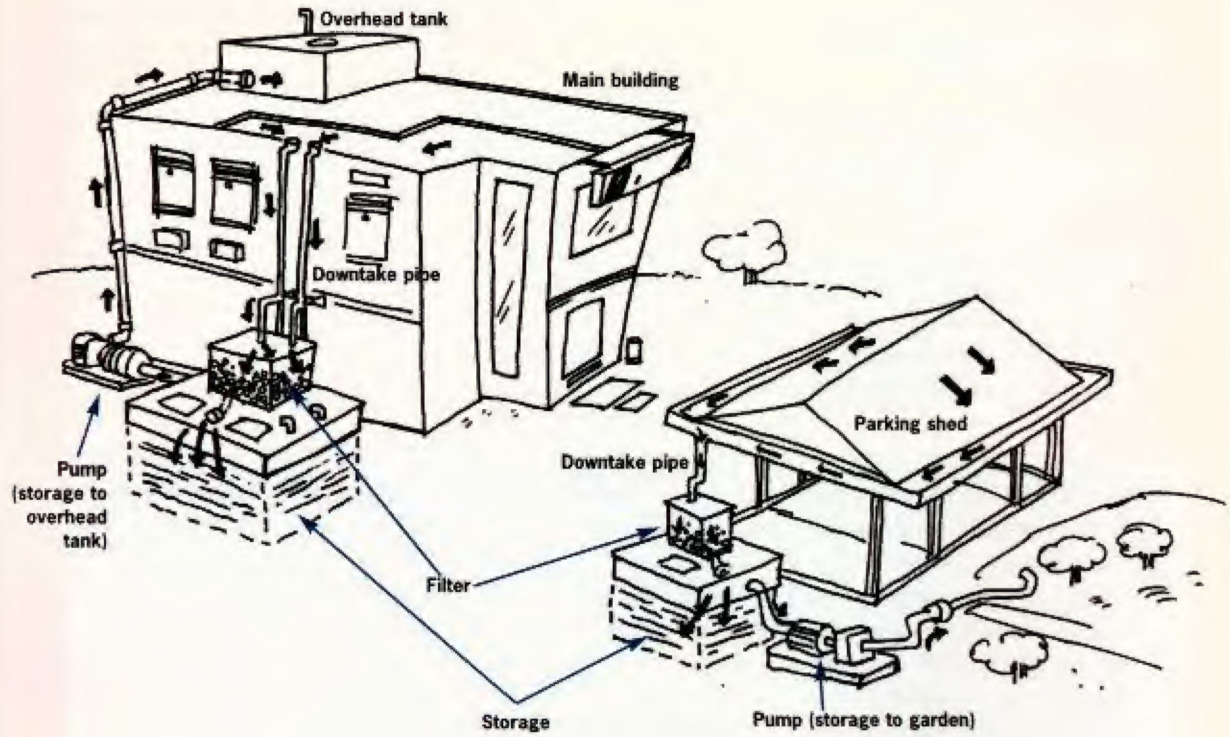
Cygnus Microsystems, located in the Cherapally Industrial Area of Hyderabad, does not get municipal water supply. The only source is groundwater which is extracted from a 107 m deep borewell. The company decided to invest in a RWH and collection system to save on buying bottled water for its 60 staff members. It harvests rain from only a third of its roof area, which suffices for drinking purposes. It spent a total of Rs 2 lakh on the RWH system, including the investment for a Aquaguard system and chloroscope for water purification. It recovered its investment in just under three years. The RWH system has been in use since 2004.

Collection of rainwater for drinking

The terrace is about 1,000 sq m but less than one third of it is used for harvesting rainwater which is used for drinking purposes. This area is cordoned off from the rest of the terrace by a 1 foot (30.5 cm) high wall. The rainwater is let out through three outlets at the rear of the terrace which are connected to 4-inch PVC pipes. The water is first passed through a filter which has gravel of different sizes. The filtered water passes into an underground sump of 65,000 litres capacity, that forms the bulk storage. A gate valve-based provision has been made to bypass the filter in case the sump is full. The sump is designed to prevent light from penetrating so that algal growth inside is avoided. Vents to release vapour pressure are provided on the sump. An arrangement to let water overflow from the sump (in case there is a fresh inlet when the sump is full) is also provided. An LED-based water level indicator has also been provided.

For day-to-day use, the water collected in the sump is pumped to an overhead Sintex tank when required. From this tank, water is piped to the consumption points, after passing through

Figure 5.1: A third of the roof provides enough drinking water



an Aquaguard filter at the point of use. Every day about 60 litres of water is used for drinking by the staff members. The stored water is sufficient to last the entire year.

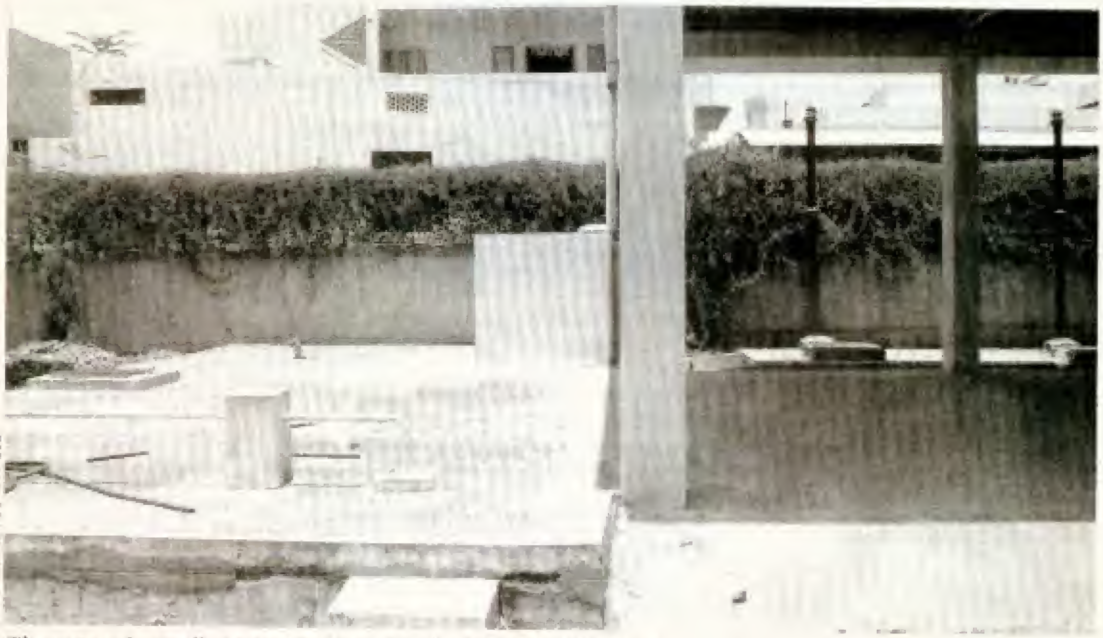
Water needed for toilets, cleaning and other uses are sourced from the borewell and the volume required is about 1,500 litres/day.

Collection of rainwater for gardening

A second sump of about 72,500 litre capacity has also been constructed. The catchment area for this sump is the roof of the parking shed. The area of the roof of the shed is approximately 275 sq m. This water is passed through a filter, which also contains gravel of different sizes. Filtered water passes to the storage sump. When required, water is pumped from this sump and used for gardening purposes. The water supplements the borewell water and is sufficient for one complete season to water the plants during the dry period. Maintenance includes only cleaning of the catchments, sump and filter once a year.

SUSHMITA SENGUPTA / CSE

Babita Ingewar of Cygnus stands in front of the filter tank on top of the underground sump



SUSHMITA SENGUPTA / CSE

The sump that collects water from the sloped roof of the shed

The total plot area is about 1 acre (4,000 sq m). With the average precipitation in Hyderabad being about 800 mm in a year, and assuming 50 per cent of this precipitation can be harvested, the total harvestable precipitation on the plot works out to be about 12 lakh litres annually. The two sumps described above account for a total storage capacity of approximately 1.32 lakh litres. An attempt has been made to ensure that the remainder of the precipitation amounting to more than 10 lakh litres annually is sunk into the ground within the premises, thereby recharging the ground water levels. Two pits have been dug to harvest the uncollected run-off and any overflow from the rainwater collection tanks. Drains running along the building channel this excess water to the harvesting pits, one of which is inside the premises. The overflow from this is diverted to another recharge pit just outside the premises. A gate arrangement is made to hold the water for some time so that the first pit has a chance to absorb the water. These RWH pits are located at the lowest point of the plot. They contain layers of gravel, metal and brickbats to increase their absorption.

Quality of rainwater for drinking purposes: As Cygnus is using only rainwater for drinking purposes, the company regularly gets the water quality tested.

Annual savings and payback: Before harvesting and using rainwater for drinking purposes, Cygnus was buying bottled water for drinking purposes at Rs 6,000 per month (Rs 72,000/year). The rainwater harvesting system was built in 2004 at a cost of approximately Rs 2 lakhs. The cost includes the Aquaguard. The cost of maintaining the system is Rs 500-1,000 per year for cleaning of the catchment, sump and filter, and also for chlorination.

The annual saving therefore works out to Rs 71,000 per year [(Rs 6,000 x 12) – 1,000]
Payback period = 200,000/71,000 = 2.75 or 2 years 9 months

System details

Drinking water tank
Total rooftop area: 645 sq m
Rainwater potential: 804 x 645 x 0.8 = 414,864 litres
Volume of storage tank: 65,000 litres
Volume of filtering tank: 6,000 litres

Gardening tank
Total rooftop area: 275 sq m
Rainwater potential: 804 x 275 x 0.8 = 176,990 litres
Volume of storage tank: 72,500 litres
Volume of filtering tank: 1,000 litres

Designed and implemented by
Babita M Ingewar, Cygnus Microsystems (P) Limited

06

Harvesting for storage

Storage tanks for harvested rainwater can be built both underground and overground. In the cities of Gujarat and Rajasthan, where rooftop harvesting was practised traditionally, rainwater from the roof was collected in underground tanks in the courtyard or within the buildings. Called *tankas*, these tanks would supply drinking water throughout the year. Some are still in use today. In Mizoram, in the north-east, tanks made of galvanised iron, tin or concrete are commonly used to store rainwater for drinking purposes. These are all overground, perched on roofs or mostly aside the hill homes. These are the traditions on which modern builders can draw inspiration from when designing their own RWH systems.

STORAGE TANKS

Storage tanks can be made out of a variety of materials ranging from cast iron sheets and polyvinyl chloride (PVC) to brick and concrete (see Table 6.1: *Types of tanks*). For all tanks, some basic precautions must be taken during construction.

Underground tanks can be made of bricks, stone slabs, slate or tiles set in cement. Regardless of the material chosen to build the tanks, they should be durable and waterproof. The tank should have a non-toxic surface, particularly when used to store water for drinking purposes. All tanks must be covered tightly to prevent contamination. Tanks need to be sited close to the catchment and point of use to reduce cost and leakages.

The earth around the tank should be able to bear the weight of the tank when it is filled up with water, which is a heavy material, a litre weighing a kilogramme. Therefore, the earth must be compacted around the tank tightly and the soil must settle thoroughly before letting any water into the tank. Those tanks which are circular in shape have a greater capacity to withstand the weight of water.

Table 6.1: Types of tanks

Various materials including plastics, bricks, GI and concrete may be used

Type	Characteristics	Life in years	Cost/litre
Polyethylene, polypropylene and other similar synthetic material	Lightweight, resistant to water, rustproof, and easily transportable.	10-15	Rs 3 - 5
Brick masonry	Long life, non-reactive, should be maintained.	15-30	Rs 3 - 4
Reinforced cement concrete	Durable and long lasting, but prone to cracking. If lined inside with ceramic tiles, it is potable.	50-75	Rs 8 - 10
Ferro-cement	Made out of cement, sand, water and strengthened with steel wire or mesh. Structurally more efficient than masonry but prone to cracking and requires maintenance.	10-15	Rs 2 - 2.50
Galvanised iron	Cast iron, when coated with hot zinc is called galvanised iron and this process makes the iron rust-proof. Is lightweight and inexpensive. Zinc dissolves in potable water; therefore, the tank must be lined inside with plastic. High maintenance required.	15-20	Rs 3 - 4

Note: Costs have been compiled based on a survey of shops and contractors in Delhi

Underground storage tanks should be made watertight by plastering the insides with cement to about a three-quarter inch thickness. Care should be taken to ensure that the water does not leak into the soil. The top of the tank should have a large enough opening so that a person can climb inside to clean the tank or undertake repairs.

Over the ground tanks must be fitted with an inlet pipe at the top of the tank, outlet pipe at the bottom, a drain pipe to clean out the tank, overflow pipe and a valve with ball float assembly. Inlet, outlet or vent pipes must be fitted during construction and not after, in order to avoid leakages.

NUMBERS OF STORAGE STRUCTURES

The number of tanks will depend on the site conditions:

- volume of rainwater that can be harvested;
- water demand;
- space available;
- layout of the building;
- size of the storage tank; and,
- budget.

When there is more than one storage tank, it can be an advantage, since they can be shut down for maintenance by rotation, and thus water can be availed at any time.

SITING AND POSITION OF TANKS

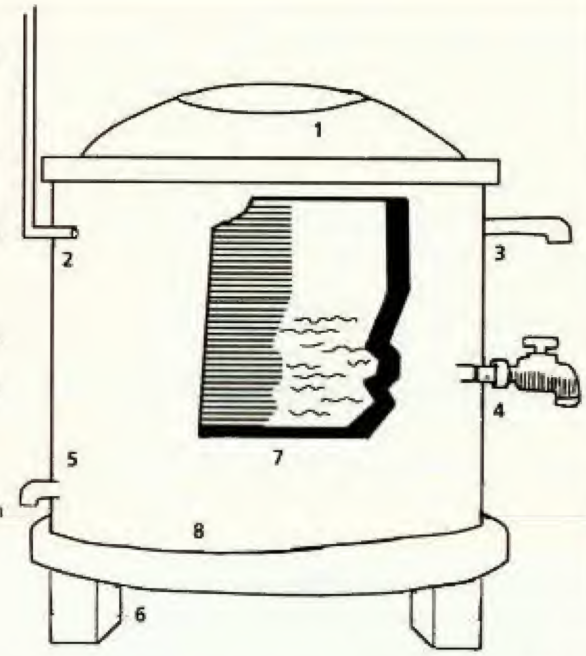
Tanks can be sited overground or underground. While using overhead tanks, the inlet pipe should be lower than the lowest downtake-pipe from the catchment. Tanks should be sited as close as possible to the catchment and point of use to reduce costs and leakages and make collection and storage more efficient. While catchments should be away from tree overhang to prevent contamination from dried leaves and bird droppings, storage tanks should be in shady places. The overflow from the storage tanks should be at minimum, 1 m away, from the foundation of the building (see Figure 6.1: *When constructing storage tanks...* and Table 6.2: *Siting of tanks*).

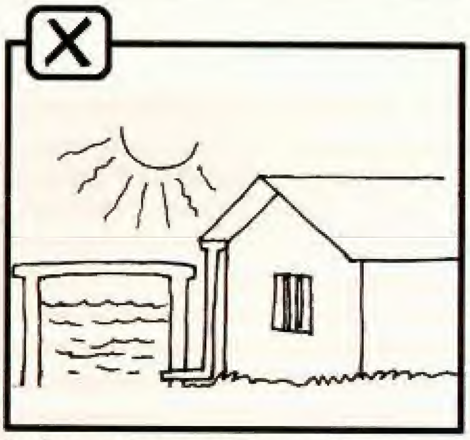
Table 6.2: Siting of tanks
Determines the effectiveness of the system

Parameters	Underground tank	Ground-level tanks
Cost	Expensive, as costs of excavation are additional	Cheapest. Can be made of any material as per the budget available
Space	Once constructed and levelled, space can be used for other purposes	Constraint in dense urban areas
Contamination	When properly made and sited, very little chances of contamination. Water will stay fresh for a long time	No chances of contamination from sewage. But there are higher chances of growth of bacteria and algae as the tanks are exposed to sunlight
Water quality	If regularly maintained, can get drinking water quality	If placed in shade away from direct sunlight, chances of contamination are reduced
Structural damage	Care must be taken during construction. Must be properly strengthened and cemented to prevent cracks as they will be more difficult to repair	Concrete, brick or synthetic materials will not damage easily but ferro-cement can crack . Easier to repair than underground tanks
Ease of accessing water	Water has to be pumped up and will use energy	If at a higher level, water can be taken out using gravity

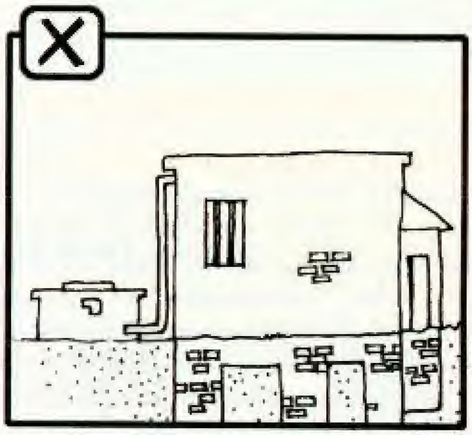
Figure 6.1: When constructing storage tanks...

1. Tank should be properly covered to prevent algal growth. The cover must be properly sized to facilitate entry for cleaning.
2. Inlet pipe should come from a level that is higher than the top of the tank.
3. There must be an overflow pipe and the mouth of the pipe must be covered with mesh to prevent entry of insects.
4. The outlet pipe should draw water from the middle – neither from the top nor from the bottom to prevent floating debris or settled contaminants.
5. There must be a drain pipe for wash out during cleaning.
6. The tank must rest on a strong and firm base.
7. The inside surface must be non-toxic.
8. Floor to slope towards drain outlet.

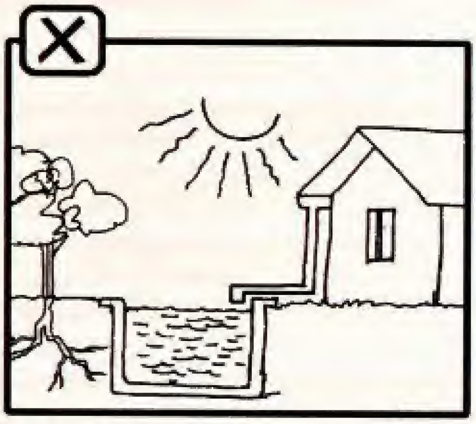




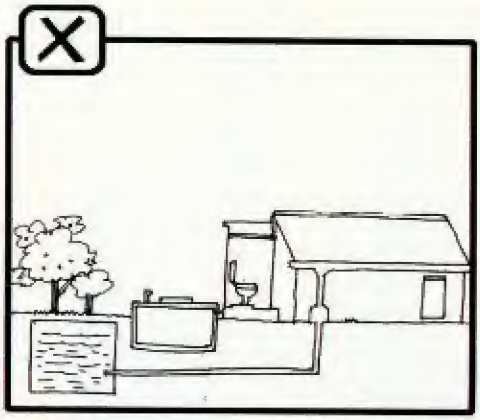
Tanks must be properly covered



Tanks must be sited at least one meter away from wall of buildings



Tanks must be sited in shady places but not directly under trees



Tanks must be sited away from septic tanks

SIZING OF STORAGE STRUCTURES

Estimating the size of the storage tank correctly is very important, as it is often the most expensive part of the system. When rainfall is distributed uniformly throughout the year, the tank size can be relatively small as water can be filled up regularly across the year. The rainy months of the year may not be coterminous with the period of peak demand. Sizing the storage tank will depend on:

- Water demand
- Average annual rainfall data for your area
- Number of rainy days
- Catchment area
- Number of dry days/scarcity period

SIZING BASED ON DEMAND FOR DRY PERIOD

If a person cannot get data on rainfall, a simple calculation based on minimum requirements for drinking and cooking for the dry period can be undertaken to calculate tank size:

Number of people in a family = 6
Per capita consumption of water = 10 litres per capita daily (lpcd)
Dry period = 100 days
Total demand for dry period = 6 x 10 x 100 = 6,000 litres
Allowance space for inlet and outlet pipes = add 10 per cent volume = 6,600 litres. A storage of 6,600 litre capacity can then be built.

A simple thumb rule to follow:

A: Sizing the tank based on availability

- Where the rainfall is available for only a short period and it is not likely to meet all your demands, then it is better to plan for the period when there is most scarcity or the period when water is not available from any other source. This is why you also need to know your number of dry days or most scarce period.
- If available rainwater is less than the demand, then the storage tank should be built to hold all the rainwater that you can collect. In this method, you will be matching the capacity of the tank to the area of the roof.

B: Sizing the tank based on demand

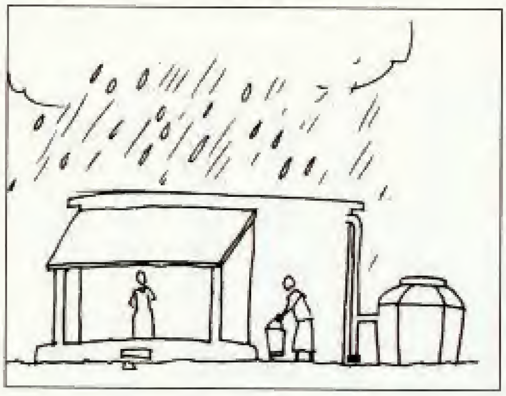
- If the available rainwater is more than the water you need, then the storage tank should be built to hold only the amount of water you need. In this method, you will be matching the capacity of the tank to the quantity of water required by its users.
- [Size of storage tank = Water demand x number of days of water scarcity]
- In places like the northeast, where rainfall is plentiful, the water demand of the entire household can be met from rainwater. But in most urban cities, it is better to store rainwater to meet only a part of your total water demand.
- This technique can be used in the absence of any rainfall data and is easily understood.

In practice, the costs, financial resources and the construction methods tend to limit the tank size to smaller capacities than would otherwise be justified by roof areas or the likely needs of consumers. For this reason, elaborate calculations aimed at matching tank capacity to roof area is usually unnecessary.

Once the size has been decided, the choice of materials will depend on personal choice, budget and locally available materials and technology.

Calculating size of tank

A. Based on availability



Rainfall = 500 mm

Rooftop area: 100 sq m

Per capita consumption: 100 lpcd

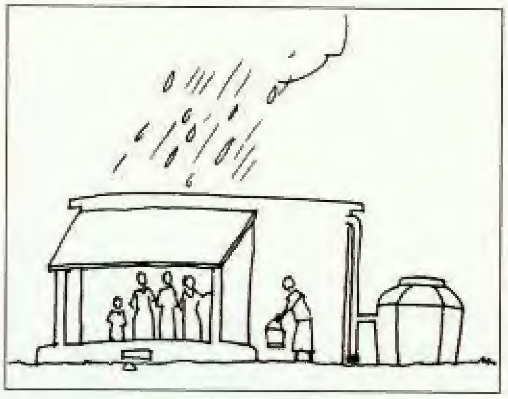
Water to store for dry days: 2 x 100 x 100 = 20,000 litres

Available rainwater: 100 x 500 x 0.8 = 40,000 litres

Availability more than demand

Sizing of tank based on demand: 20,000 litres

B. Based on demand



Rainfall = 250 mm

Rooftop area: 100 sq m

Per capita consumption: 60 lpcd

Water to store for dry days: 5 x 60 x 100 = 30,000 litres

Available rainwater: 100 x 250 x 0.8 = 20,000 litres

Demand more than availability

Sizing of tank based on availability: 20,000 litres

SIZING BASED ON WATER BALANCE METHOD (OR RAINFALL)

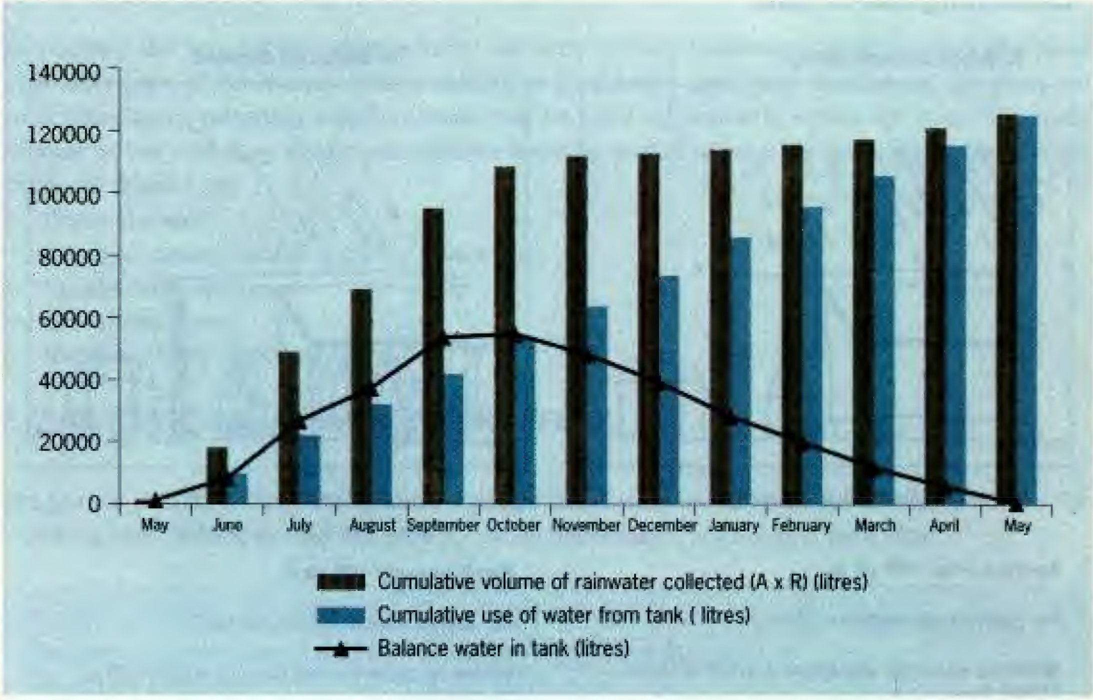
This technique involves detailed record keeping of rainfall received, volume accumulated in the tank, water being used and net water left in tank. The size of the tank is calculated based on the maximum volume of water remaining in the tank. MM Sharma of Hastinapur Colony used this method to arrive at the size of his storage tank. Sharma incorporated the rainwater harvesting design at the construction stage in 1995. The storage tank for rainwater has been placed under the floor of the house.

Municipal water in this area is supplied on alternate days and that too for an hour only. Not only that, the water is supplied at odd hours, often as early as 4 AM. During periods of scarcity, water is supplied every three days, for 45 minutes or even less.

Sharma kept detailed records of rainfall, volume being accumulated in the tank, water being used and net water left in the tank. He calculated the balance of water that could be stored in the tank after deducting the probable daily use of water – 350 litres. The maximum water likely to be in the

M M Sharma inside his rainwater storage tank

Graph: Monthly rainwater collected, monthly use of water



Source: MM Sharma, Hyderabad

tank was calculated at 54,436 litres. From this, he arrived at the optimal storage size of the tank – 54,800 litres. However, Sharma constructed a bigger tank of about 90,000 litre capacity, keeping in mind the structural design of the house and making allowances for higher rainfall. He says that a simple rule of thumb would be to construct a tank that would hold between 25-45 per cent of the total water harvesting potential.

The total cost to build the tank came to Rs 33,000. Additional costs were incurred for a polyurethane tank (Rs 3,000), an electric pump (Rs 2,000) and Rs 3,000 for pipes and plumbing. In all Sharma spent Rs 41,000. This is about 8.2 per cent of the total amount spent for the construction. A substantial part – about Rs 18,000 – of this money was spent on making a strong RCC cover for the tank, which also serves as the floor for the kitchen, storeroom and living room floor area. He says that it took him just 7 years to recover the cost. He has also stopped using water sourced from the 55 m deep borewell from the year 2003.

System details

Total Rooftop Area = 160 sq. m
Rainwater Potential = 804 x 160 x 0.8 = 102912 litres
Volume of Storage Tank = 90,000 litres
Volume of Filter Tank = 25,000 litres
Mesh size of the three filter chambers

1. In The First Filter Chamber = 2.5 cm x 2.5 cm
2. In The Second Chamber = 1 cm x 1 cm
3. In The Third Chamber = 2 mm x 2 mm

Cost = Rs. 41,000 in the year 1995

07

Harvesting for recharge

Recharge structures channelise rainwater into the aquifer, an absolute necessity in the context of the rapidly declining groundwater table across India. Recharging also serves to prevent flooding in cities during intense rain spells. In coastal areas, it serves to control saline intrusion.

The design of a recharge system depends on site-specific conditions such as topography, hydro-geology, rainfall, available space and economic feasibility.

THUMB RULE: FOR RECHARGE STRUCTURES

- Do not recharge soils that have a heavy content of clay, which expands when wet and shrinks when dry. This can cause damage to building foundations.
- Do not recharge if the land slopes towards a building. Water will run toward the foundations.
- Good soils for recharge are sand, loan, loamy sand and sandy loam.
- Ensuring the quality of water recharged is a very important consideration for recharge systems.

TYPES OF RECHARGE STRUCTURES

Recharge structures are mainly of the following types:

a. Recharge pits (with and without bores)
b. Recharge trenches (with and without bores)
c. Recharge wells

In addition, dugwells or tubewells that are no longer in use can be converted into recharge structures. Usually, recharge wells are combined with settlement/desilting tanks while pits and trenches are constructed without settlement tanks.

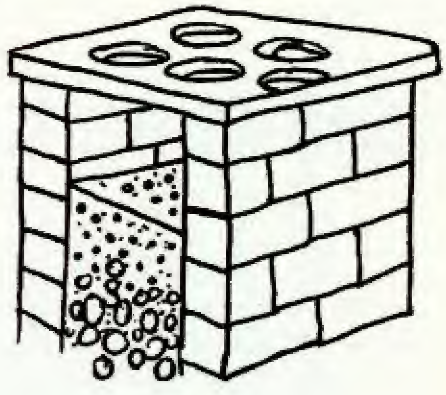
Table 7.1: Characteristics of different recharge structures

The depth of a recharge pit, length of a bore-pipe in a well and volume of a trench are important factors

Recharge pit	Recharge pit (with bore)	Recharge well	Recharge trench
Used in places where soil is sandy Eg. Chennai, Puri	Where the top layers of soil/rock may not be permeable	For larger catchments	From paved ground catchments such as near gates
Shallow pits with filtering materials	Shallow pit lined with bricks on the sides. Filled with filtering materials and has a recharge bore-pipe	Has a settlement tank, a sump filled with filtering materials and one or more recharge bore-pipes	Large trench with filtering materials and recharge bores
No constructed base. Open to the soil at bottom, perforated cover on top	No constructed base. Open to the soil at bottom with a perforated cover on top	Constructed base. Not open to the soil	Constructed base. Not open to the soil. Metal grill cover
Design consideration: Permeability of soil	Design consideration: Availability of permeable layer at relatively shallow depths	Design consideration: Settlement tank to slow down the water flow. Length of bore-pipe should be above groundwater level	Design consideration: Volume of trench to exclude space occupied by filtering material

RECHARGE PIT

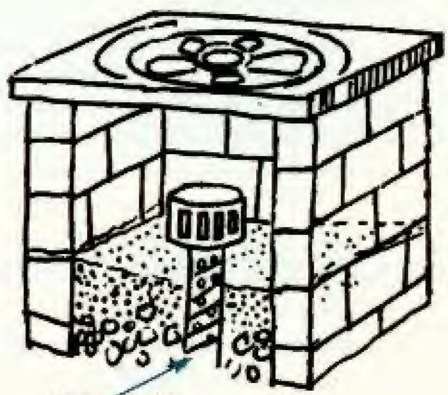
Figure 7.1: Recharge pit



This is the simplest recharge structure, suited for small catchments. It is mostly used where the soil is permeable to recharge the shallow aquifer, or provides water for the roots of plants. Also called percolation pits, they can be circular or rectangular and have no inlet or overflow pipe. They are located in low-lying areas so that water can automatically flow into the structure. Ideally, there should be one percolation pit for every 23 square metre (sq m).

A recharge pit is about 0.5-0.6 m on each side. Its depth can range from 0.6-1.5 m, depending on the catchment area and rainfall. The pit is filled with gravel, pebbles, sand or broken bricks to filter the water before it reaches the aquifer (see Figure 7.1: *Recharge pit*).

Figure 7.2 Recharge pit with bore



Recharge pits require relatively clean water to prevent its clogging and should be sited well away from the base of buildings. They require very little maintenance, though, except periodic cleaning of the filter materials.

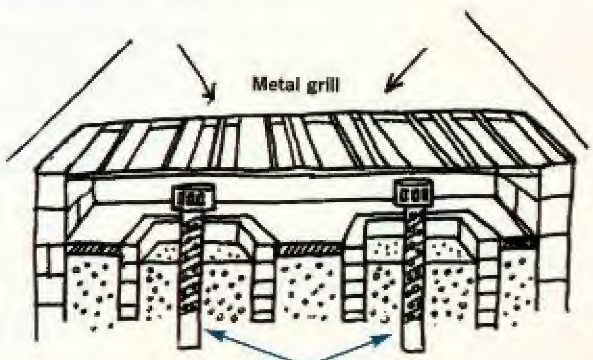
Where the soil is not permeable such as clayey soils, the recharge pits can be fitted with a recharge bore (see Figure 7.2: *Recharge pit with bore*) through which the water reaches the first permeable stratum. The bore can be 150-250 mm in diameter and the depth of the bore will depend on the depth at which permeable strata can be found.

The recharge bore can be drilled with a manual auger unless hard rock is found at a shallow depth. The pit can be lined with a brick/stone wall with openings (weep-holes) at regular intervals. The pit can have a perforated cover.

RECHARGE TRENCH

A recharge trench is excavated in the ground and refilled with porous media like pebbles and boulders. It is a continuous trench and suitable for places where there is no drain, channels or a rainwater pipe to collect run-off and where water is wasted without being trapped, leading to waterlogging on the road. It collects the run-off from paved or unpaved areas draining out of a compound and could be dug across the slope of the land.

Figure 7.3: Recharge trench with bore



A recharge trench does not have inlet and overflow pipes. It should be covered with a metal grill cover or perforated RCC slab on top.

A recharge trench can be 0.5-1 m wide and 1-1.5 m deep. The length of the recharge trench is decided on the basis of the run-off expected and space available to dig the trench. As in the case of recharge pits, a trench can be combined with recharge

bores to reach deeper strata. The base of the trench can be cemented or left as it is. Similar to pits, the trench has filter materials such as brickbats, pebbles and gravel.

RECHARGE WELLS

Water enters the aquifer through a recharge well, unlike a borewell, which extracts groundwater. It is used where the soil is not so permeable allowing for easy recharge and where it is necessary to reach deeper ground to find permeable strata. For instance, when there is a clayey or rocky layer on top of permeable strata, the recharge pipe is designed to reach that stratum.

It consists of a tank or a pit filled with filter materials such as coarse sand, pebbles and gravel and a recharge bore that will reach the permeable stratum. A pit is excavated to a depth of about 1.5-2 m, and in the middle of the pit, a borehole is drilled. It can be made with a manual auger or drilling equipment depending on the geology of the site. The recharge pipe, which is fitted into the recharge bore, has a diameter of about 150-300 mm. The pit has a cement concrete base and the sides are lined with brick masonry or RCC walls. In some parts of the country, circular concrete rings are used to make a circular recharge well.

The depth of the bore will depend on the hydrogeology of the site. The pipe has perforations or slots for a part of its length so that water can seep into the bore. Bore pipes can be made of mild steel (MS) or polyvinyl chloride (PVC). The former is expensive, prone to rusting and difficult to slot. In contrast, PVC pipes are cheaper, non-corrosive and easy to slot. However, they may leach toxic chemicals after prolonged use, a distinct disadvantage.

The space between the recharge bore and the sides of the recharge pit is filled with filtering materials such as gravel, pebbles and coarse sand. This portion of the recharge bore can also be covered in jute or coir materials for additional filtering. The recharge pit has an inlet and an overflow pipe and is covered with a concrete slab that can be lifted to let a person in for maintenance activities.

Good practice for recharge

The recharge bore should never reach the aquifer. It should terminate some way above the water table.

This ensures that the water being recharged is further filtered through sufficient thickness of soil before reaching the aquifer.

As a thumb rule, the depth of the bore should be above the post-monsoon level of groundwater.

Figure: Depth of recharge bore

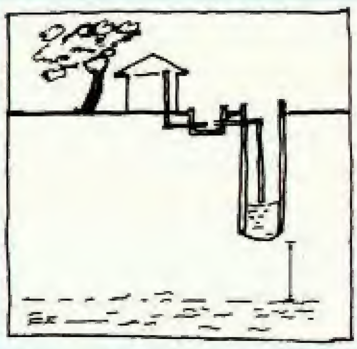
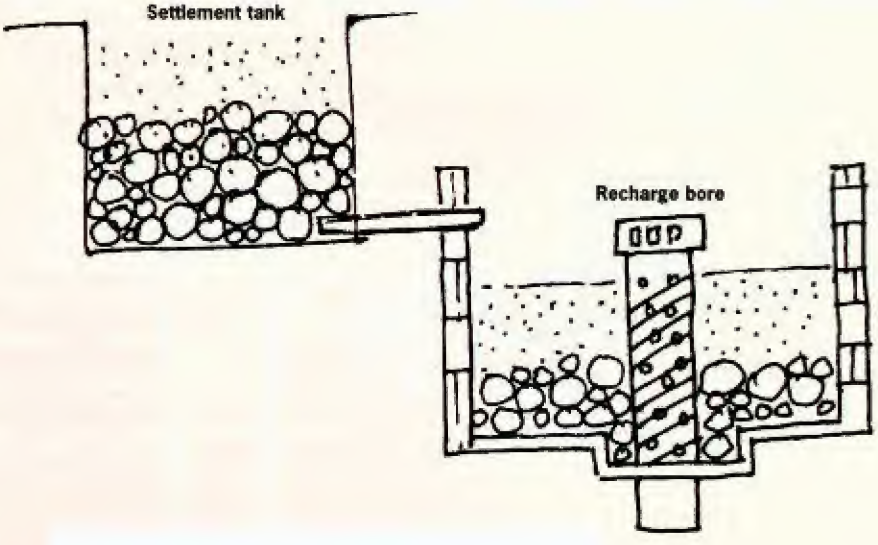


Figure 7.4 Recharge well with settlement tank



Settlement/desilting chamber

A recharge well is usually combined with a settlement chamber that provides the first level of filtration. This is a small tank or pit that collects the first run-off and allows the water to settle before going into the recharge well. The silt and sediments settle at the bottom while clean water flows into the recharge well.

For catchments with a higher sediment load, the filtration capacity of the chamber can be enhanced through an in-built filtration system. The tank is divided into two chambers by a baffle wall. Water enters the first chamber and the silt settles at the bottom. Clearer water from the top flows into the second chamber which is provided with filter materials. The filtered water is led into the recharge well.

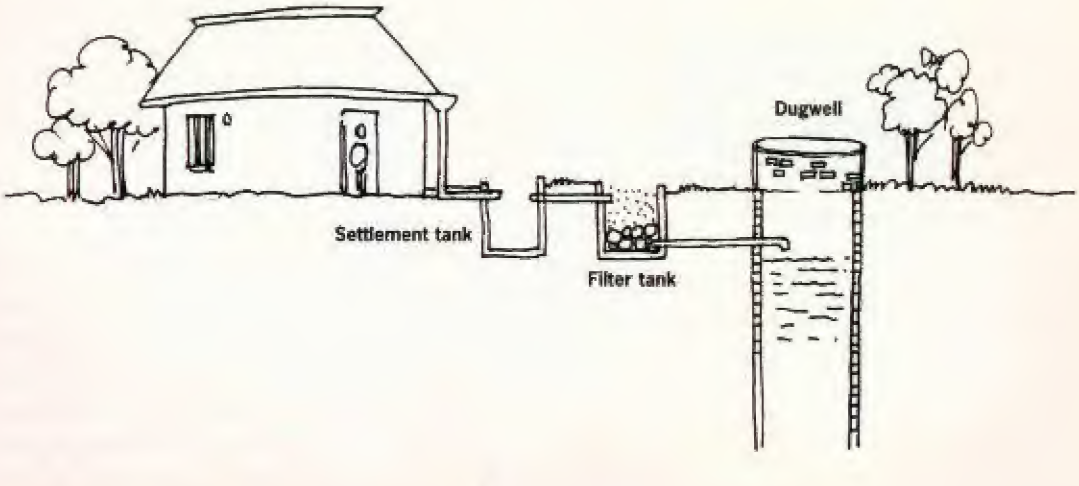
RECHARGING THROUGH ABANDONED BOREWELLS OR DUGWELLS

Dugwells or borewells that have ceased to hold water and are therefore defunct can be used as recharge wells. The cost of sinking a recharge bore is thus saved. Water from the roof or other catchments can be led through a pipe to the abandoned borewell or dugwell. In the case of a tubewell, the top 1-2 m of the cast-iron casing can be removed and replaced with a slotted or perforated pipe so that more surface area is available for the water to percolate. The perforated portion can be covered with a coir/jute or nylon mesh for additional filtration. If a dugwell is used for recharge, the well lining should have openings (weep-holes) at regular intervals to allow seepage of water through the sides. Dugwells should be covered to prevent mosquito breeding and entry of leaves and debris.

Casing of tubewell (top), slotted pipe (below)

RECHARGING IN-USE BOREWELLS AND DUGWELLS

In many places, borewells and dugwells are recharged directly. In such cases, abundant precaution must be taken to ensure that the water is adequately filtered before it reaches



the aquifer. Water from the roof or other catchments can be led to a settlement tank and a recharge pit with filtering materials dug a little distance away from the borewell or dugwell.

SIZING OF RECHARGE STRUCTURES

Rainwater takes some time to percolate into the soil. Therefore, the structures must be so designed to hold most (at least two-thirds) of the water that runs off during the most intense spell of rain in a day, which, on an average, does not last longer than 30-40 minutes in India. Thereafter, the rainfall slows down even in cases of continuous rainfall. Coastal cities like Kochi, Mumbai and cities in the North-east have longer intense spells and cities like Delhi or Ahmedabad have shorter intense durations. To determine the size of the recharge structure, the volume of rainfall during the most intense spell of 15-30 minutes is calculated for the given catchment area.

(See Annexure 1 for rainfall intensities of select cities)

Sizing a recharge trench

As water for the recharge trenches enters directly from unpaved or paved areas, a higher quantity of filter materials is needed. While sizing the recharge trench or trough, allowance has to be made for at least half the volume of the trench to be used up by filter materials.

Catchment area (A): 100 sq m
Run-off coefficient (C): 0.6
Peak rainfall intensity in 15 minutes (I): 16 mm
Rainwater volume in 15 minutes of rainfall: 100 x 0.6 x 16 = 960 litres
Volume of the trench should be 960 litres.

Filter materials take up at least half the capacity of the trench, the size of the recharge trench should be double the capacity needed to hold the run-off, ie. 1,920 or rounded to 2,000 litres.

Dimensions of the trench: length x width x depth: 2 m x 1 m x 1 m = 2 cu m or 2,000 litres

Table 7.2: Sizing of recharge structure

Volume of water during most intense period of rainfall determines size

Description	Delhi	Mumbai
Catchment area	100 sq m	100 sq m
Duration of intense spell	15 minutes	30 minutes
Average peak intensity of rainfall/hour (based on 25-year average)	64 mm	100 mm
Run-off co-efficient (average of different types of catchments)	0.6	0.6
Volume of water generated x peak rainfall x co-efficient	100 x 16 x 0.6 = 960 litres	100 x 50 x 0.6 = 3,000 litres
Recharge pit volume: 2/3 of rain volume	640 litres	2,000 litres
Dimensions of recharge pit (l) x (b) x (d)	1 m x 0.75 m x 1 m = 750 litres	1 m x 1 m x 2.5 m = 2,500 litres
Space for filter materials and the invert level*	750 – 640 = 110 litres	2,500 – 2,000 = 500 litres

***Note:** The invert level is the depth at which the incoming pipe joins the recharge pit will have to be taken into account to calculate desired dimensions

Step by step construction of recharge well

In search of permeable strata to sink a borehole

Step 1 (Figure 1): Excavate the earth

Step 2 (Figure 2): Prepare a footing (base: 15-20 cm) with plain cement concrete (PCC) on which the masonry brick wall will be erected. Prepare masonry on RCC walls.

Step 3 (Figure 3): Make a borehole to facilitate groundwater recharging.

Step 4 (Figure 4): Insert the bore pipe with slots into the borehole. Cover the slotted portions with jute coir.

Step 5 (Figure 5): Fill the well with filter materials. Cover the tank (RCC/stone slab/metal grill). Provide a manhole for entry into structure.

Figure 1: Excavate earth

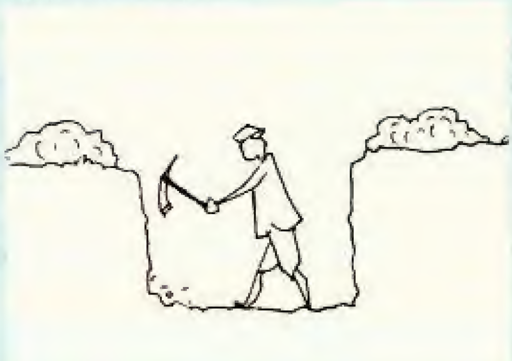


Figure 2: Prepare masonry on RCC walls

Figure 3: Drill a bore hole

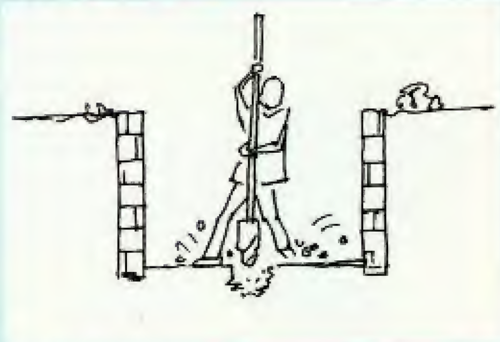
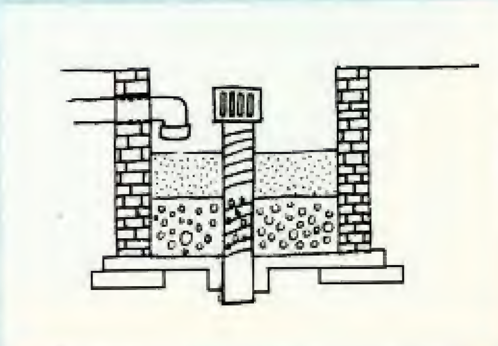


Figure 4: Insert bore pipe

Figure 5: Fill bore with filter material



POINTS TO NOTE FOR CONSTRUCTION OF RECHARGE STRUCTURES

Before beginning the construction of a recharge structure, the following must be assessed:

- Soil and rock profile of the site;
- Quality and quantity of water;
- Intensity of rainfall;
- Depth to the aquifer and its properties;
- Type of land use, industrial, agricultural or residential;
- Type of catchment, paved or unpaved area.

Soil and rock profile: Soil and rock profile determine the kind of recharge structure. Where soils or substrata is of low permeability, wells or shafts penetrating the substrata are the only means

Stages of construction of a recharge well, Delhi Gymkhana Club

Excavatiing earth prior to setting up system

Excavation and drilling of bore pipe

Construction of brick wall

Complete recharge well with filter material

of recharge. Where there is a shallow aquifer overlaid by clay, it can be removed and a recharge pit can be constructed. If the geological profile is of hard rock, it is better to construct storage systems. Recharge or percolation pits are suitable for smaller catchments where there is no space available to construct recharge wells or trenches.

Quality and quantity of water: The quality of water is critical to aquifer recharge. Filtration systems must be constructed to remove suspended solids and biological and chemical impurities. Accumulation of debris or other organic impurities will facilitate the growth of bacteria and algae, which clogs recharge structures and slows down the rate of recharge. The quality of water affects the efficiency and the life of a recharge structure. Water for recharge should be far away from sewers, areas where detergents, pesticides, herbicides or other chemical substances have been used.

Intensity of rainfall: The rainfall intensity in a particular site will influence the size of the recharge structures. In places of very high rainfall intensity, a large volume of water will accumulate quickly and the recharge structure must be large enough to hold the rainfall. The recharge bore must have a larger diameter and deep enough to deliver the water quickly and efficiently to the aquifer. Where the intensity is low, the structure can be smaller with a shallow bore.

Depth of the aquifer and aquifer properties: Recharge is best done where the groundwater table is at a minimum depth of about 8 metres below ground level. The aquifer must be thick, porous, permeable and homogenous for ideal recharge conditions.

CASE STUDY

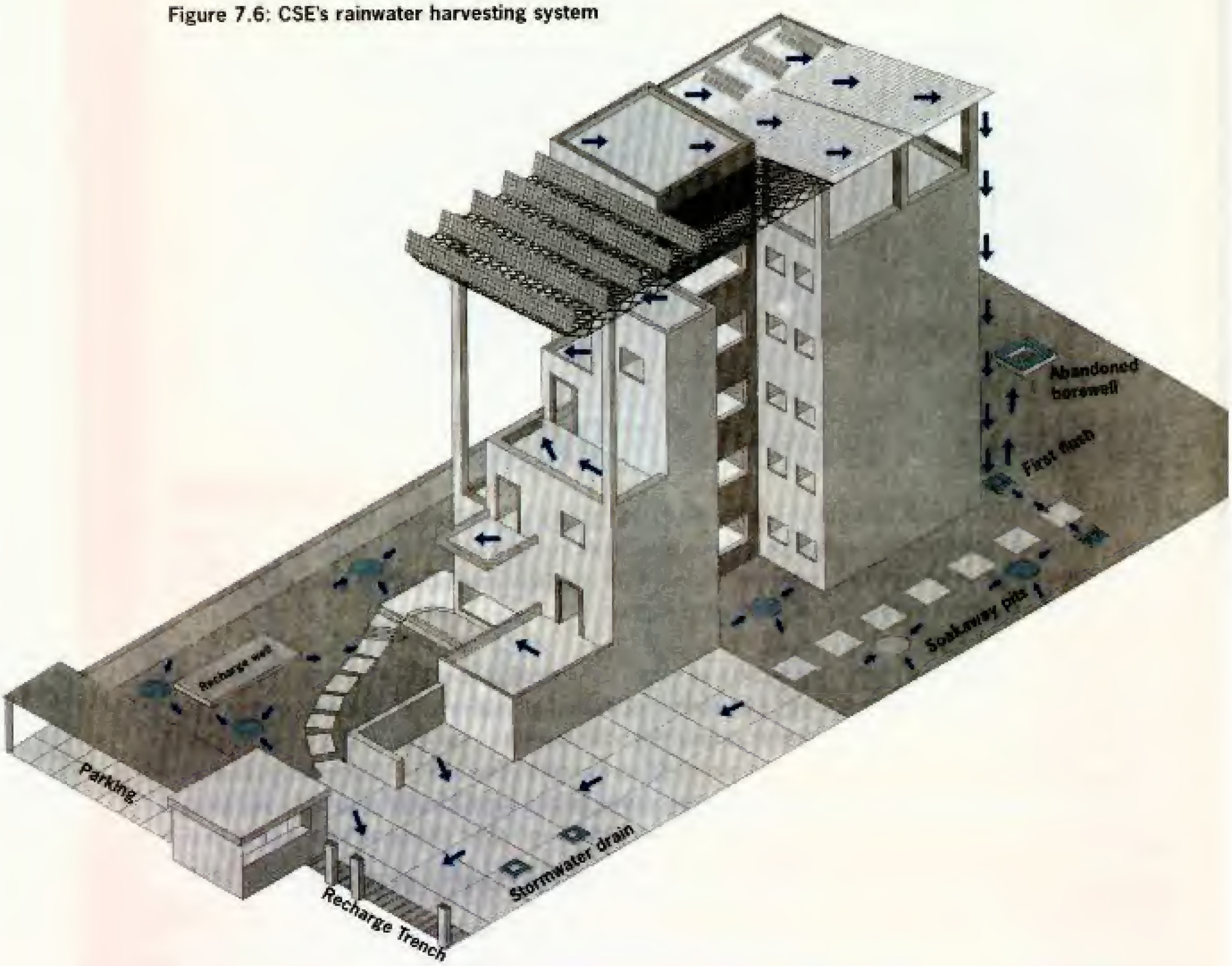
CENTRE FOR SCIENCE AND ENVIRONMENT, NEW DELHI

The Centre for Science and Environment (CSE) built a system to harvest rainwater in 1999, when the organisation was just beginning to initiate its rainwater harvesting (RWH) advocacy. The plan was to build a live demonstration of a RWH system in an urban area to motivate others.

A simple system was designed. It comprised of the following:

- Recharge pits with bores to reach water to the first permeable layer of soils around the building in the unpaved areas.
- Recharge trench at the front of the building to arrest water from flowing away.
- Recharge well (coverted from an old storage tank) to recharge water from the roof areas.
- Using a defunct borewell to recharge water from roof areas.

Figure 7.6: CSE's rainwater harvesting system



Source: Centre for Science and Environment, New Delhi

Recharge pits

In order to capture the rainwater that falls on the unpaved area around the building, 13 recharge pits have been constructed all around the building. Each of the pits have a brick-lined collection chamber. In the middle of this sump a 30 feet (9.14 m) bore was dug and a recharge pipe was inserted. The pipe was slotted in the top portion of the pipe to allow for the entry of the water. The slotted portion is also wrapped in coir to add to the filtration process. The top of

the pipe is covered by a pot to prevent the entry of debris into the pipe. A perforated RCC cover is placed over the pit.

> Dimensions of the recharge pits [length (l) x breadth (b) x depth (d)]: 0.6 m x 0.6 m x 0.5 m
> Unpaved area catchment: 615 sq m

Recharge trench

The recharge trench is situated at the gate and prevents any water from going out of the building. It is a long trench with three recharge pits and covered with an iron grill.

> Dimensions of the recharge trench (l x b x d): 6.2 m x 0.7 m x 0.5 m = 2.17 cu m
> Dimensions of recharge pit within trench (l x b x d): 0.3 m x 0.3 m x 0.3 m = 0.9 cu m
> Total trench volume: 3.07 cu m
> Unpaved catchment area: 133 sq m
> Rainfall intensity used for design: 90 mm/hour or 22.5 mm/15 minutes
> Rainwater harvesting potential in 15 minutes: 33 x 0.023 x 0.5 = 1.53 cu m
> Space for filter materials: 1.53 cu m
> Volume of trench should be: 1.53 + 1.53 = 3.06 cu m
> Actual trench volume: 3.07 cu m

Recharging through a defunct borewell

Rainwater from the rooftops that drains towards the rear of the building is channeled to a defunct borewell.

Pipes bring water from the roofs at two different levels to a central point at the northeast corner of the building. There is a small collection chamber (1 ft x 1.5 ft x 1.5 ft) that collects water from three pipes. From here water is led down through a vertical pipe that is concealed within the building. The mouth of this pipe is covered with a mesh to filter out gross contaminants such as leaves and other debris. Water is channeled from the bottom of the vertical pipe to the abandoned borewell.

The top portion of the defunct bore was removed and replaced with a slotted pipe. A sump was built and lined with a brick wall. The top of the sump is covered with a RCC cover to prevent debris from entering the system. The sump is filled with filter media made up of pebbles and stones to a depth of 30 cm. The bore pipe is 45 m deep.

Recharge well

Rainwater that falls on the open terrace in each of the four floors of the building is channeled to an open pond. The pond acts as a settlement tank. The overflow of this tank is led to a recharge well located in the front of the building.

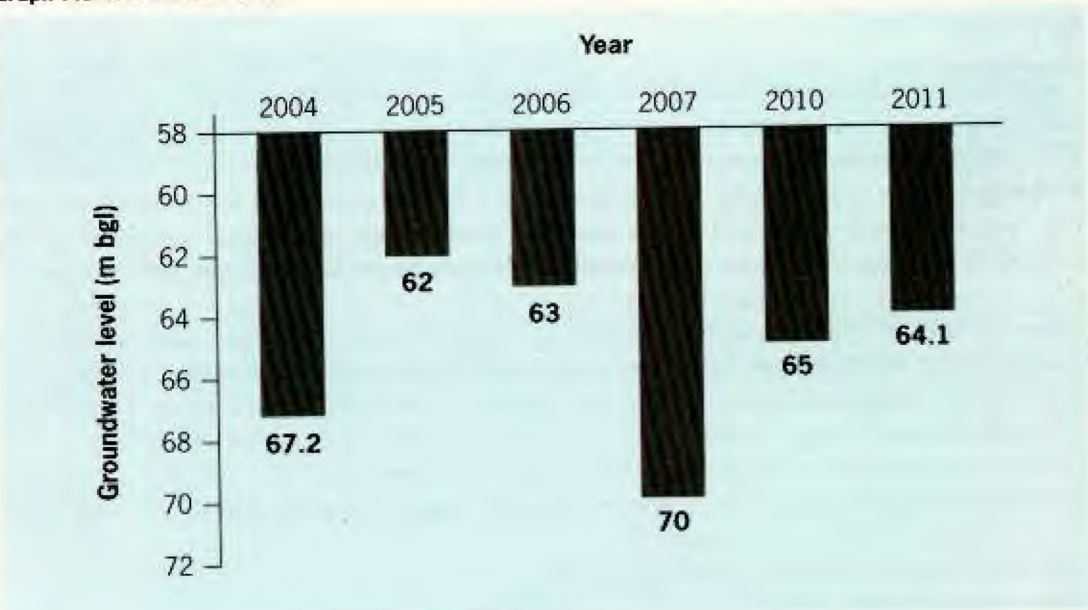
> Dimensions of the recharge well (l x b x d): 2.8 m x 1.75 m x 3.0 m
> Filter materials are filled up to a depth of 75 cm.
> Volume of the recharge well sump = 11.03 cum
>
> Rooftop area for the recharge well: (Floors 1-5) = 35 + 25 + 23 + 9 + 20 = 112 sq m
> Rainwater harvesting potential in 15 minutes = 112 x 0.023 x 0.8 = 2.06 cu m

In this case, the recharge well sump was constructed as a storage tank and later converted into a recharge well and therefore the volume of the sump is larger than what would be required to retain rainwater in a spell of 15 minutes.

Raising of stormwater drains

Openings into the municipal stormwater drains were raised to prevent rainwater from flowing into them.

Graph 7.1 Groundwater level



Source: Centre for Science and Environment, New Delhi

IMPACT

This institution barely gets any municipal water supply. Therefore, it has to depend on borewells. The demand for water has been steadily rising as the number of persons have increased by 20 per cent. Nevertheless, the post-monsoon groundwater level has been maintained around 65 metres below ground level (m bgl).

08

Filter systems

Rainwater is relatively clean and thus does not need complex filtering. Commonly used filter systems based on a combination of sand and gravel will keep out most organic pollutants. If rainwater is used for drinking purposes – and where money is not an issue – residents can set up household filtering systems at point of use.

There are a number of in-built mechanisms within a rainwater harvesting (RWH) system that ensures that the water finally stored or recharged is of good quality. The number and type of filter mechanisms used would depend on the end-use of the rainwater harvested.

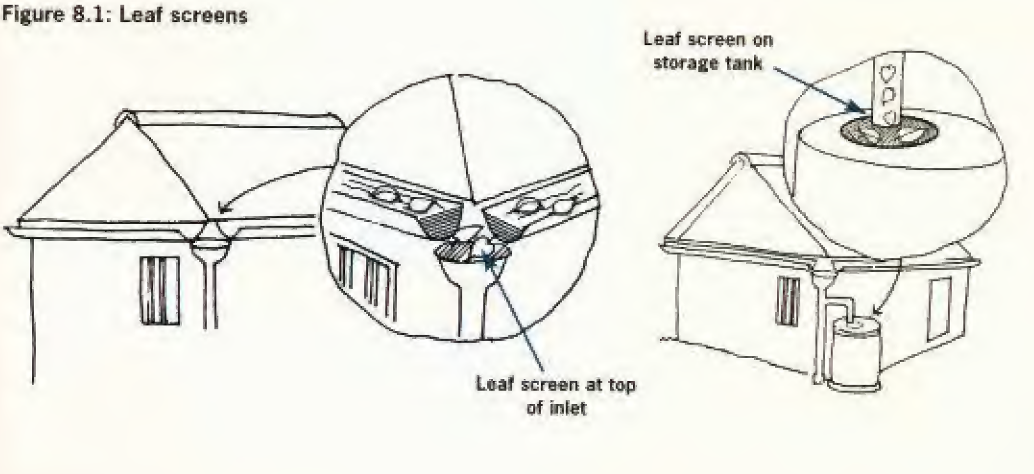
Four types of filtration processes can be used in the RWH system:

- *Separation or screening:* This is the first level of filtration and separates out gross pollutants such as leaves, droppings and other materials.
- *First flush:* At the second level, the first spell of rain containing dissolved impurities – the first flush – are allowed to flow away.
- *Filtration:* Filters remove dissolved organic and inorganic particles in the rainwater, before it is collected.
- *Settlement tanks:* Settling tanks remove silt and other coarse materials.

LEAF SCREENS

As a first step when collecting rainwater leaves, animal litter and other debris should be kept out from the roof catchment area, particularly, where there is a tree overhang. Simple meshes or *jalis* made of iron, wire, nylon or plastic can be used for this purpose. The leaf screens (see Figure 8.1: *Leaf screens*) can be placed anywhere through the system as per convenience – on the roof at the entrance of the down-pipes or gutters, at the end of the down-pipes or gutters, at the entrance of storage tanks. Leaf screens must be regularly cleaned to remove accumulated debris. Otherwise, the pipes will get clogged and prevent water from flowing, which can be a health hazard.

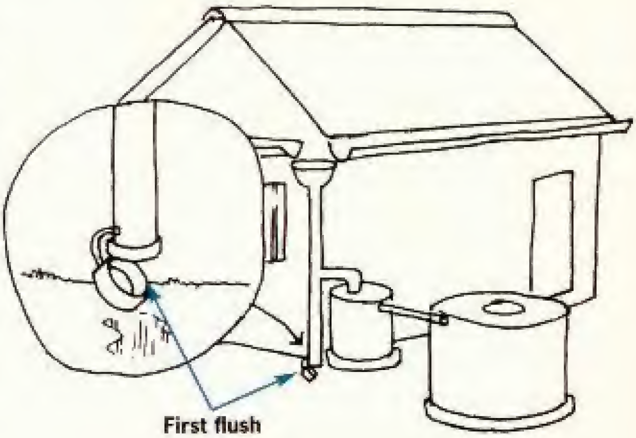
Figure 8.1: Leaf screens



FIRST FLUSH DEVICES

Catchments tend to accumulate dirt and dust, and after a long, dry summer, the first spell of rain will absorb dust particles from the air as well as from the roof catchments. Leaf screens cannot keep out these contaminants. To remove these, the simplest way is to throw away the initial spell of rainwater. The first flush device ensures this (see Figure 8.2: *First flush device*).

Figure 8.2: First flush device



There is no exact calculation that determines the amount of rainwater that should be discarded. It depends on a variety of factors:

- The condition of the catchment: the dirtier the catchment, more will be the water that needs to be discarded;
- Type of catchment: Smooth catchments and sloped roofs will need less water to wash off contaminants instead of rough catchments and a flat roof;
- The dry period before the rain: After a long and dusty summer, more water will be needed to get rid of the dissolved dust particles and other contaminants. As against this, in hilly areas, where there is frequent rainfall, after the first spell of rain, less water needs to be discarded;
- Area of the catchment: Small catchments require less water to flush out contaminants as first flush; and,
- Intensity and amount of rainfall: This is one of the most important factors that determine the amount of water that will need to be discarded. If the first spell of rain is an intense burst of rain, then in a short span of time, more water will be delivered. When the intensity of rain is less, it will take a longer time to get rid of contaminants and begin delivering clean water.

First flush devices range from simple manual devices – that require a person to monitor and regulate the flow of rainwater – to automatic systems based on fixed volume and flow rate principles. For Indian conditions, where rain falls in short, intense rain spells the manual arrangement is a practical solution. Pacey and Cullis recommends that the first 15-20 minutes of the first rainfall be discarded as first flush.[2]

Manual downtake pipe flap or valve: The simplest first flush device is the downtake pipe which has a closed end with a cap. During the first spell of rain, this cap is opened so that the first flush of water flows down the pipe into the drain. The cap is shut later and the water is directed into a pipe that leads to the storage tank or recharge structure.

Fixed volume first flush system: Another option is to have a tank of a fixed volume that can receive the

R K SRINIVASAN / CSE

First flush diverter manually operated by end cap

initial rainwater. The intake pipe is closed off with a manual or automatic valve. The water in the tank can be emptied out and used for gardening or irrigation. An automatic shut-off system can also be a simple ball-cock system that is commonly used in water storage tanks to cut-off supply of water. When the first flush tank is filled up, the supply will be directed to the storage tank.

What should be the volume of a first flush tank? As outlined before, this depends on a number of factors. As a thumb rule, for an area of 100 square metre (sq m), a first flush volume of about 40 litres should be thrown away. Thus, for every sq m of roof area, a volume of 0.4-0.5 litres should be thrown away as first flush.[1]

Systems are also available whereby separate arrangements for removing first flush and filtration are not necessary. In the case of readymade filter solutions such as found in Madhya Pradesh, the first flush is incorporated within the system.

VINAYAK WATER SOLUTIONS

First flush diverter manually operated by a valve – this system is being used in Dewas, Madhya Pradesh

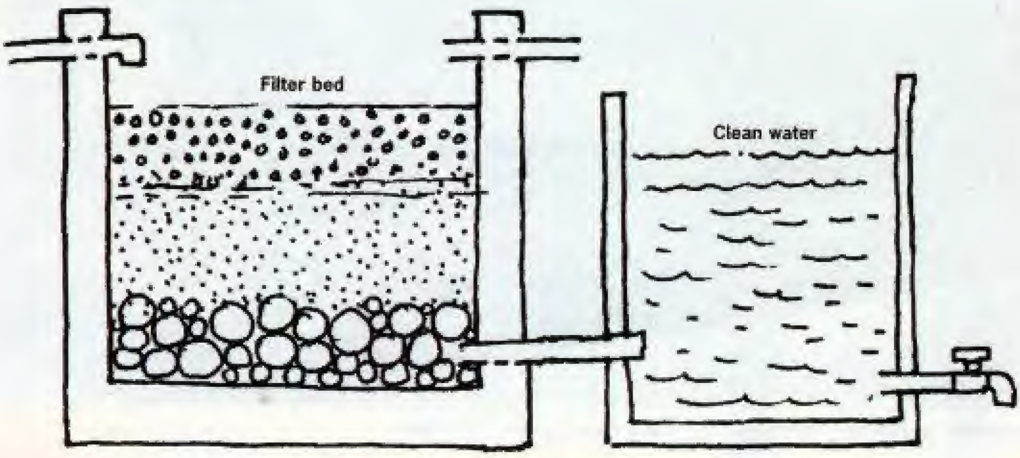
FILTERS

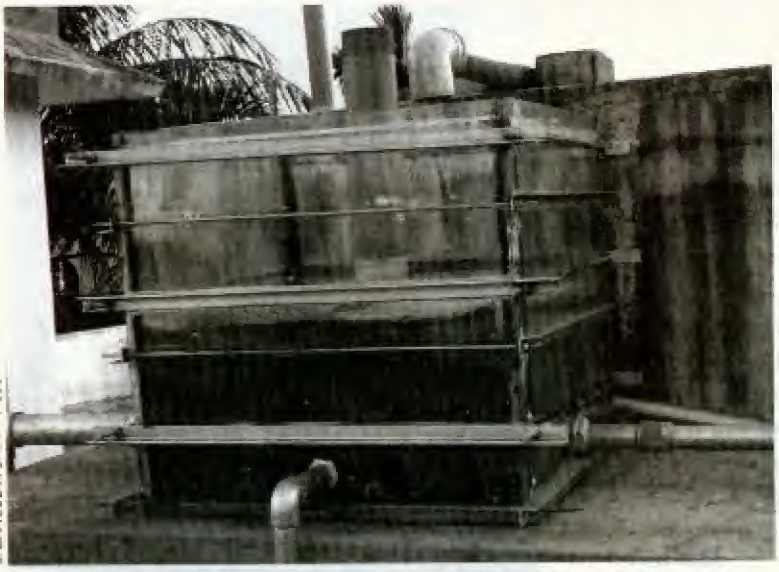
Filters are needed to remove fine particles of dust or bacteria from the water. A filter unit is a chamber filled with filtering media such as layers of boulders, pebbles, gravel, coarse sand and fibre to remove debris and dirt from water before it enters the storage tank or recharge structure. Charcoal can be added for additional filtration if water is to be used for human consumption.

Selection of a filter depends on:

- Purpose of use
- Quality of run-off
- Type of catchment
- Amount of silt load
- Type of recharge structure

Figure 8.3: Simple sand filter




SALAHUDDIN SAIPHY / CSE

Type of simple sand filter being used in the Association of Engineers building, Kolkata. It has gravel and pebbles


SUSHMITA SENGUPTA / CSE

A type of simple sand filter designed by V N Shroff. It has a combination of sand, pebbles and charcoal within a PVC pipe. A nylon wire mesh covers the inlet

Simple sand filter: A simple bucket or drum can be used for filtration of water into a storage tank. The drum must be lined at the bottom with gravel of average size 3 mm in diameter. Then a layer of coarse sand is added which is the main filtering medium. Over this another layer of coarse gravel is put to prevent the sand being scoured by the inflow of water. Where water is being recharged, the filtration materials are coarser and made up of pebbles and gravel. The simple sand filter (see Figure 8.3: *Simple sand filter*) can be enhanced to function more efficiently by adding materials such as charcoal and jute coir.

The basic combination of sand and gravel is today used to make ready-made filters such as Varun filter, Dewas filter, Amber filter and Vinayak filter.

Dewas filters: The filter consists of a PVC pipe, 140 mm in diameter and 1.2 m in length. It is placed horizontally. It is divided into three chambers, all filled with pebbles of different sizes. The first chamber has the smallest pebbles, approximately 2-6 mm in diameter; the second,


SALAHUDDIN SAIPHY / CSE

A variation of Dewas filter used by Ulhas Paranjpe in Mumbai

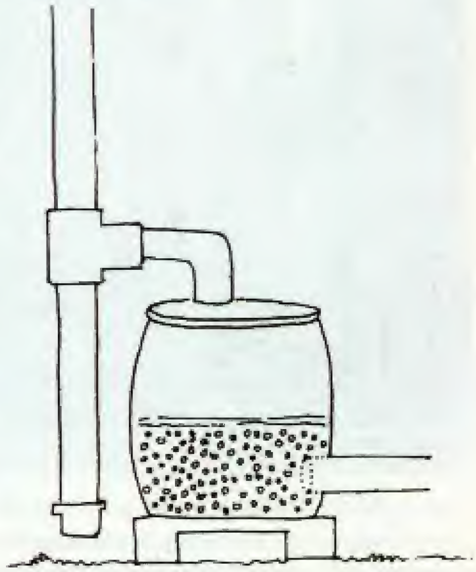
pebbles of 6-12 mm and the third, pebbles of 12-20 mm diameter. At the end of the final chamber, there is a wire mesh, through which clean water flows. The water thus filtered is used to recharge groundwater. The filter was designed by engineers of the public health engineering department, Dewas.

Ferrocement filter: A ferrocement tank is built using jelly (coarse blue metal) and charcoal as the filter medium. A 6-inch layer of charcoal is laid over a 6-inch layer of jelly of 40 mm thickness. This type of filter is widely used in the RWH systems in Kerala, fitted over ferrocement tanks. A ferrocement filter of 20-30 litres capacity costs approximately Rs 3,000.[3]

Varun filter: This simple filter was designed by S Viswanath, a Bangalore-based RWH expert. An ordinary high-density polyethylene (HDPE) or ferrocement drum of about 90-100 litres is used to house the filter made of a combination of sand, gravel and charcoal. The lid of the drum is punched with holes to let in water and prevent larger contaminants such as leaves and other large substances. As an alternative, nylon mesh can be tied across the top of the drum.

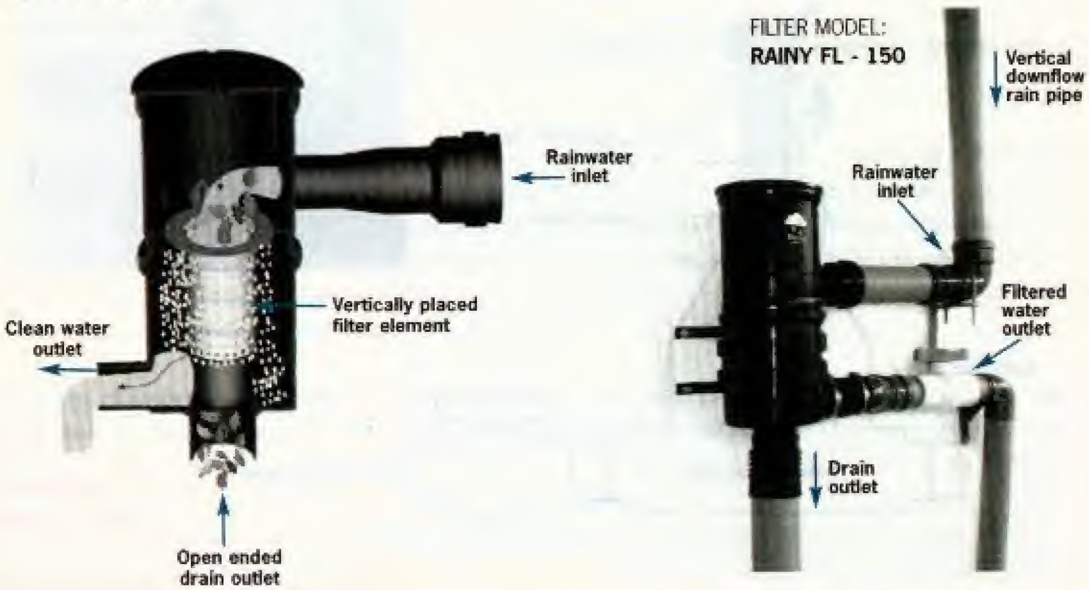
The drum is filled to a height of maximum 12 inches (0.3 metres) with layers of sponge and sand or gravel and sand (see Figure 8.4: *Varun filter*). Addition of charcoal as a filter medium helps in improved filtration. This drum can handle water from a roof catchment of about 50 sq m and an intensity of about 50 mm/hour. For a 100 sq m catchment two such drums can be used. A filter that can service a rooftop area of 100 sq m (price in Bangalore in 2006: Rs 4,500).[4]

Figure 8.4: Varun filter



Rainy filter: The filter medium used here is a low carbon galvanised steel cylinder with a mesh size of 250 microns. The filter is enclosed in an outer casing of polyethylene and the filter can withstand a rainfall intensity of 75 mm/hour. The working of the filter is based on the principles of cohesive force and centrifugal force. The filter comes in four sizes meant for a roof catchment area of 110 sq m, 225 sq m, 350 sq m, and 500 sq m. The price ranges from Rs 5,850 to 21,375

Figure 8.5: Rainy filter



AMBER

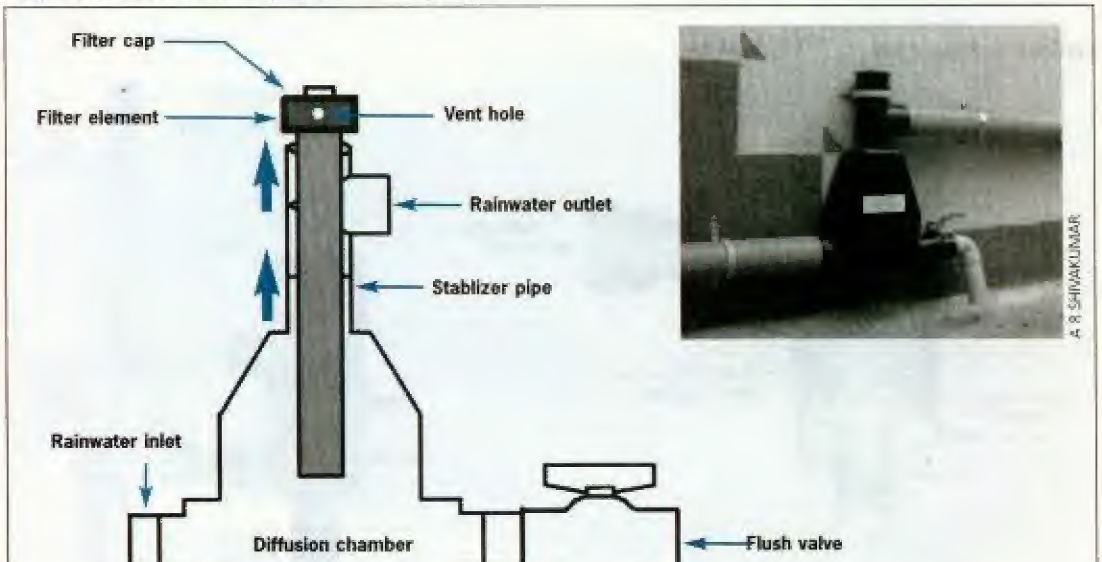
Amber filter

(inclusive of taxes). It cannot remove bacteriological contaminants. It can be used for recharge systems where the water will further undergo filtration through the soil. It is designed and marketed by Farmland Rain Water Harvesting System based in Chickamagalur, Karnataka (see Figure 6.6: *Rainy filter*).

Amber filter: This has been developed by Association for Motivation of Biosphere and Environmental Revolution (AMBER), a non-governmental organisation working in Bhopal. It is fitted on to the downtake pipe and consists of a section for the first flush and another section containing the filter. At both ends of the filter there is an iron or nylon mesh that acts as a sieve. A charcoal layer is in the centre of the filter, which has layers of gravel, pebbles and sand, arranged symmetrically on both sides. The entire filter length is about a metre long for an area of about 100 sq m. Filtered water goes down the downtake pipe. A 6 inches dia filter costs Rs 6,500.

Pop-up filter: The pop-up filter has been designed by Karnataka State Council of Science and Technology and is currently being manufactured by Raj Irritech (P) Ltd, Ahmedabad. It has three components – rainwater receptor, flush valve and filter element. In the receptor, rainwater flows through the downtake pipe provided with a flush valve which flushes out the the first flow along with leaves and dust. Water received in the receptor flows upwards against gravity through a filter element that filters out most of the floating elements and allow water to stabilise in this filtration zone. It later flows out through an outlet, which can be led to a storage tank. The filter element is mounted on a vertical stabiliser pipe with a friction fit.

Figure 8.6: Cross-section diagram of pop-up filter



Source: Karnataka State Council of Science and Technology

Figure 8.7: Cross-section diagram of Vinayak filters

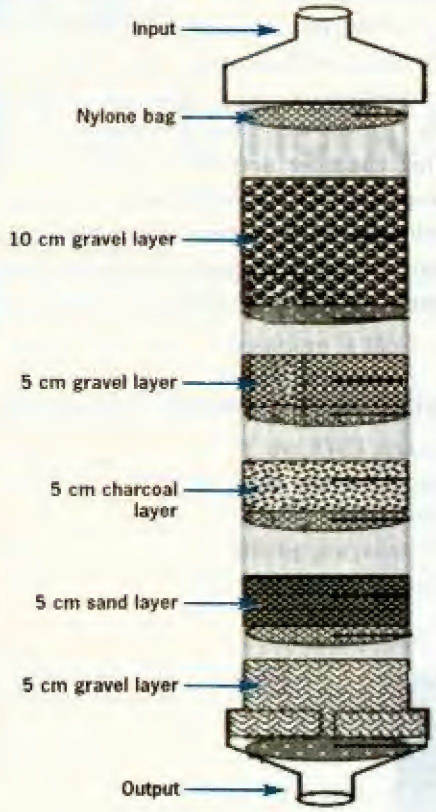


Table 8.1: Cost of Vinayak filters

Diameter of filter	Cost (Rs)
4 inches dia	1,150
5 inches dia	1,350
6 inches dia	1,500

Source: Vinayak Water Filter Solutions, Dewas

Vinayak filter

The filter element needs to be cleaned periodically during the rainy season to remove the filtered material. As such, when the filter element gets clogged, a built-in safety mechanism pushes out the filter element from the stabiliser pipe and allows the water to flow out freely. This prevents flooding of the rooftop due to the clogged filter. When rainwater starts flowing out of a vent hole provided on the top of the filter element, it is the first indication of the filter clogging.

A pop-up filter of 110 mm can handle water from a roof area of 1,000 sq feet (93 sq m) with an annual average rainfall of 1,000 mm. The cost of a filter that caters to a roof area of 1,200 sq feet (111 sq m) is Rs 3,990.

Vinayak filter: This filter has been developed by Vinayak Water Solutions, Dewas. The filter has a central layer of charcoal (5 cm layer). On top of the charcoal layer is 5 cm of gravel and below the charcoal layer is 5 cm of sand. Each layer of filter material is separated by a nylon mesh. At both ends there are identical layers of gravel (10 cm). The entire filter media is enclosed in a PVC pipe that is closed at the top with an inlet pipe and at the bottom with an outlet pipe (see Figure 8.6: *Cross-section diagram of Vinayak filter*).

Desilting chambers or settlement tanks: Desilting chambers are designed to remove silt and other floating impurities and prevent clogging of the recharge structure. They are necessary for catchments that produce a large load of silt, tree leaves and other debris such as schools, colleges, colonies, farmhouses or other large establishments. Typically, rainwater that is collected from the catchment is diverted by drainpipes to a settlement or desilting tank and then directed into the recharge well.

A desilting chamber is like an ordinary storage container having provisions for inflow of water from the catchment, outflow of water to the recharge well and allows for overflow of water. It can be divided by a baffle wall into two compartments where the first compartment collects water from the catchment, reduces the velocity of water, resulting in settlement of coarse impurities at the bottom. Water from the first chamber overflows from above the baffle wall to the second chamber, which is filled with filtering materials like gravel and pebbles. This serves to further arrest impurities in the water.

Apart from removing silt from the water, the desilting chamber acts like a buffer in the system. In case of excess rainfall, the rate of recharge, especially of borewells, may not match the rate of rainfall. In such situations, the desilting chamber holds the excess amount of water till it is soaked up by the recharge structure. Any container (masonry or concrete underground tanks, old unused tanks, pre-fabricated PVC or ferrocement tanks) with adequate capacity of storage can be used.

Sizing the desilting chamber: This is similar to the principles used for sizing the recharge pit. *(See Chapter 7, Section 2 for details)*

09

Maintenance

The standard of maintenance of a rainwater harvesting (RWH) system determines both the quality and quantity of water harvested. Rainwater is one of the cleanest sources of water, except where the atmosphere is likely to be polluted by industrial or other urban activities. To make the most out of the RWH system, a number of preventive and curative measures must be undertaken as part of a regular maintenance and monitoring programme. These measures are meant for every part of the RWH system – the catchment area, the conveyance system of pipes and gutters, storage tanks and recharge systems.

Water from a clean roof catchment is nearly of potable standards and needs little further treatment even for drinking purposes. Keeping the roof clean is the simplest and the most cost-effective way of collecting quality rainwater.

PREVENTIVE TIPS

The roof

- Clean the roof catchment and outlets thoroughly before the onset of the rains. Thereafter, clean the roof regularly throughout the rainy season.
- Wash or sweep the roof to clear away dust, leaves, bird droppings and other debris.
- Trim overhanging tree branches. This will minimise entry of leaves, branches, bird droppings and animals into the catchment area.
- On metallic roofs, paint rusted portions and fix holes. On tiled roofs, fix broken tiles.
- Ensure that the entry of downtake pipes or gutters are screened with a leaf-mesh, which will prevent the entry of debris into the RWH system.
- Ensure that the roof has a proper slope towards the outlets, which in turn slope towards the downtake pipes so that the water flows naturally away from the roof and does not stagnate.


SUSHMITA SENGUPTA / CSE

Clean, cemented roof catchment, residence of V N Shroff, Indore


SUSHMITA SENGUPTA / CSE

Corrugated iron roof catchment, Woodstock School, Mussoorie

Leaf screens

- Clean the roof and leaf mesh regularly, especially before the onset of rains.
- Replace damaged or defective screens or meshes.
- Ensure that the leaf screen is fixed in such a way that water drains out of the roof easily.

Gutters and downtake pipes

- Gutters must be securely fixed to the walls. Check that wall brackets are in good shape and holding up the gutters well. That way water will not spill over.
- Check that gutters are sloped towards the downtake pipes.
- Clean gutters of accumulated debris, dirt and dust before the onset of rains. If possible, cover the length of the gutter with a leaf mesh or screen.
- Check that downtake pipes are not broken.
- Inspect joints for leakages.

SUSHMITA SENGUPTA / CSE

Downtake pipe, Padmini Niwas Hotel, Mussoorie

SUSHMITA SENGUPTA / CSE

Downtake pipe neatly fixed on wall, Woodstock School, Mussoorie

First flush devices

- Clean removable caps on downtake pipes of any sludge or stagnant water.
- Clean stagnant water in first flush tanks.
- If there is a float mechanism, check if it is in proper working order.

Filters

- Take out the filter materials, wash or if necessary, replace them.
- Replace coir, sand and other fine materials.
- Remove, wash and replace sand.
- Clean out accumulated silt.

Storage tanks

- Clean tank, remove silt, and dirty water at least once a year.
- Whitewash walls if necessary.
- Ensure that the tank is properly covered and all light excluded to prevent growth of algae and bacteria.
- Make timely repairs to prevent cracks, especially in ferrocement tanks.
- An additional measure to keep the water clean could be the provision of a coarse filter or a mesh at the end of the inlet pipe leading into the tank.


SUSHMITA SENGUPTA / CSE

Storage tank after its annual cleaning, at residence of late O P Sharma, Indore

Recharge structures

- Annually, desilt recharge structures.
- Remove and wash filtering materials such as pebbles and coir and replace when necessary.
- Put iron mesh to cover all stormwater drains.
- Clean open drains regularly by removing deposits of sand and gravel.
- Cover drain outlets and inlets with iron mesh.

Impact of defective construction and maintenance

Defective construction and badly maintained rainwater harvesting (RWH) systems can be a source of problems. In Cuddalore, Tamil Nadu, RWH systems have been implemented in all buildings as part of a mandatory rule, the state government has provided standard specifications for construction of RWH systems under the Groundwater Regulation Act, 2003. However, when scientists from the Vector Control Research Centre, Pondicherry undertook a study in 2006 on vector proliferation in the town, they found that faulty maintenance practices had led to the stagnation of water and mosquito breeding.

Table: When maintenance takes a back-seat

Type of maintenance fault	Result
Lack of regular cleaning of filling material in percolation pits/tanks	Stagnation of water in percolation pits
Obstruction of roof and gutter with garbage in tiled houses	Stagnation of water on roofs
Cracks on sidewalls of percolation pits	Entry of ovipositing female mosquitoes
Blockage of conveyance pipes by garbage	Stagnation of water on roofs
Obstruction of PVC pipes linked to wells with debris	Stagnation of water
Damages to conveyance structure	Leakage of rainwater into street drains or seepage of sullage water into the system
Open plastic/iron drums used for harvesting rainwater	Promoted mosquito proliferation
No conveyance pipe in system or percolation pits	System does not work, stagnation of water

Source: Centre for Science and Environment, New Delhi

MAINTAINING COMMUNITY RWH SYSTEMS

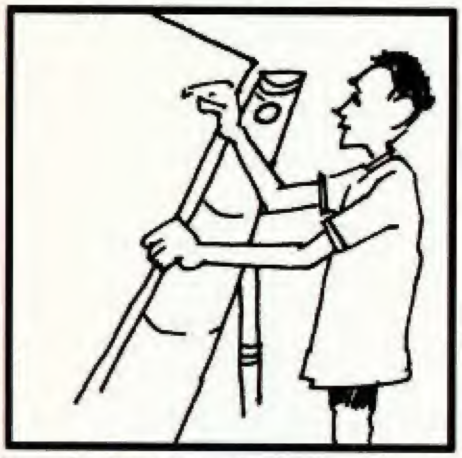
Maintaining RWH systems in colonies or high rise buildings presents additional challenges. The success of RWH depends on its regular inspection and maintenance. From the very beginning, systems must be made to put in place for this to happen automatically. The system will include:

- Identification and training of persons who will carry out regular maintenance.
- Fund allocation for maintenance.
- Setting up a committee and a system for election of members who will be responsible for maintenance.
- Awareness creation of all residents so that all citizens contribute to the maintenance.

Maintenance tasks

Keep the catcment area clean

Keep the outlets clean



Keep the gutter securely fixed

The filtertank needs to be kept clean

The storage tank needs to be washed

The trench has to be free of debris

Step-by-step cleaning of recharge structures

PHOTOS: DEBASHIS TUDU / CSE

Remove parts of recharge trench for cleaning

Remove silt from recharge bore

Remove filter material (pebbles) from pit

Wash the filter material

Clean recharge bore and filter material

Put back the parts of the recharge trench

Poorly maintained structures

SALAHUDDIN SAIFY / CSE

Rooftop covered over by leaves

SUSHMITA SENGUPTA / CSE

Cracked downtake pipe

SUSHMITA SENGUPTA / CSE

Downtake pipe not connected to the roof

SUSHMITA SENGUPTA / CSE

Settlement chamber filled with debris (malba)

SUSHMITA SENGUPTA / CSE

Broken conduit system (pipe leading from rooftop to recharge well), garbage dumped around the recharge well

SUSHMITA SENGUPTA / CSE

Cracked RCC cover of a recharge well

10

Rainwater quality

One of the first questions that people ask about rainwater – is it of good quality? Is it fit for drinking or cooking? Can it be used for household purposes? Rainwater is less susceptible to contamination, especially when compared to groundwater, which has become a major source of water. It is usually free of colour and odour and there is less likelihood of it being contaminated by human faeces or chemicals – which leach into groundwater. Rainwater also does not contain minerals. Thus its use is an effective way to lower groundwater extraction and avoid groundwater-related diseases (see Box: *Avoid diseases, use rainwater*).

Rainwater gets contaminated at various points in the system when it is poorly designed or maintained (see Table 10.1: *Sources of contamination and prevention methods*). This is why, when designing the system, it is important to keep quality issues in mind. Thereafter, regular cleaning and maintenance measures ensure good water quality. Where rainwater is used for drinking, additional protection can be secured through a variety of measures.

Avoid diseases, use rainwater

In recent years, fluoride and arsenic contamination of groundwater has become widespread in India. It results in fluorosis, (which affects the dental, skeletal and neurological systems) and arsenicosis (cancers of the skin, bladder, lung) and aggravates diabetes and kidney malfunctions. Treatment is expensive and mostly irreversible.

While there are efforts to develop filters to separate arsenic and fluorides out of water these are expensive and need to be handled carefully. A simple method to avoid contamination would be to harvest rainwater and use it for drinking and cooking purposes. This method is being taken up on a large scale in affected areas in India and Bangladesh.

TYPES OF CONTAMINANTS

Rainwater is contaminated when it combines with heavy metals and other impurities that may be present on the roof, in tanks or other parts of the system:

- **Debris:** Visible contaminants such as leaves, twigs, bird or animal dropping, insects and dust. These materials can harbour invisible micro-organisms as well as traces of pesticides or other chemicals.
- **Minerals:** Found naturally in the environment as inorganic salts such as sodium bicarbonate, sodium chloride and other similar salts of calcium or magnesium. The presence of minerals makes water hard. Rainwater is virtually devoid of salts and is normally slightly acidic because of dissolved carbon, sulphur or nitrogen.
- **Metals:** Contamination takes place from metallic elements such as lead, copper, iron and zinc found in construction material used for roofing and in pipes and fittings. This could affect the look and taste of water.
- **Agricultural chemicals:** These are usually found where surface land areas are used as catchments and where agricultural chemicals have been used for crops such as fertilisers or pesticides.
- **Construction chemicals:** A wide array of chemicals are used in the construction industry, such as water-proofing chemicals, water repellents, tile adhesives, anti-corrosive substances and even simple paints.

Table 10.1: Sources of contamination and prevention methods

Part of RWH system	Contaminants & source	Prevention methods
Roof	• Dust/air pollutants from surrounding area • Bacteria from bird/animal droppings • Organic debris such as leaves or other plant materials from overhanging trees • Toxic chemicals if roof is treated, painted or is made of aged asbestos	• Regular cleaning of catchments • Trim overhanging branches • Leaf mesh • First flush • Avoid painted/treated roofs • Avoid harvesting water in areas close to places where there may be continuous presence of air pollutants such as from cement plants and other industries
Conveyance pipes and gutters	• Toxic chemicals, when conveyance systems are made of materials that can leach toxic substances • Accumulated dust or debris	• Ensure conveyance pipes are made of non-toxic substances • Regular cleaning of pipes and gutters • Fixing gutters and pipes them appropriately to prevent water stagnating
Storage tanks	• Mosquito larvae where tank water is not properly protected to prevent entry of mosquitoes • Dust or debris, silt, organic debris • Growth of bacteria, algae	• Proper sealing of covers, regular cleaning of tanks • Filter systems at entry points into tanks • Use non-toxic materials such as plastic, metal, cement, brick masonry, ferrocement • Prevent sunlight from entering tank
Underground storage systems	• Dust, silt, bacteria, organic debris, chemical contamination, sewage	• Proper sealing of covers • Regular cleaning of tanks • Filter systems at entry points into tanks • Avoid water from areas where agricultural chemicals are used
Recharge systems	• Dust, industrial air pollutants, silt, bacteria, organic debris, chemical contamination, sewage resulting from non-maintenance of recharge tanks and filter media	• Avoid water from catchments in industrial areas • Regular cleaning of desiltation chamber and recharge tanks • Annual maintenance of filter media • Site tanks far away from sewage pipes/soak-pits • Regular repair of storage tank walls

- **Volatile organic compounds:** These are either present in the air and absorbed by rain or rises from land surfaces. There is a danger of contamination when water is harvested in industrial areas and typical contaminants could be oil, grease, solvents and petroleum products.
- **Biological contaminants:** These can be bacteria, viruses or fungi and the source for this type of contamination is the RWH system itself. These may be disease-causing or benign, but in either case they must be removed for potable purposes. Microbiological contaminants are never found in the rainwater itself, but may be present in different parts of the system such as the roof, the storage containers, gutters or even in the filter systems, where maintenance and cleaning are not regularly done.

PURIFICATION OF HARVESTED RAINWATER

When rainwater is used for drinking, an extra level of purification can be undertaken. This is over and above the filtration and maintenance measures. Biological contaminants such as bacteria, viruses, protozoans and cysts can be removed by a variety of disinfection measures, which include boiling, chlorination, micro-filtration and ultra-violet (UV) treatment. There are also readymade systems based on activated carbon, reverse osmosis and ion exchange that are more expensive. The World Health Organisation has set some quality benchmarks for the maximum level of contaminants allowed (see Table 10.2: *Quality guidelines for harvested rainwater*).

Table 10.2: Quality guidelines from harvested rainwater

Parameter	Guideline value
Faecal coli form of E. coli	Not detectable in a 100 ml sample
Aluminium	0.2 mg/l (level likely to result in consumer complaints)
Cadmium	0.003 mg/l
Copper	2 mg/l
Chloride	250 mg/l (level likely to result in consumer complaints)
Fluoride	1.5 mg/l
Iron	0.3 mg/l (level likely to result in consumer complaints)
Lead	0.01 mg/l
Sodium	200 mg/l (level likely to result in consumer complaints)
Sulphate	250 mg/l (level likely to result in consumer complaints)
Turbidity	5 NTU (level likely to result in consumer complaints)
Total dissolved solids	1,000 mg/l (level likely to result in consumer complaints)
Zinc	3 mg/l (level likely to result in consumer complaints)

Note: These are guidelines of the World Health Organization, 1996
Source: Luke Mosley 2005, 'Water quality of rainwater harvesting systems', SOPAC Miscellaneous Report, February, p 16

Boiling: This is an effective purification method and simple to carry out. After the water comes to a boil, it should be allowed to do so for 10-15 minutes. This kills off the micro-organisms. Boiling can also drive away some of the volatile organic compounds. It can also have concentrations of harmful contaminants that do not vapourise such as lead, mercury, pesticides, and nitrates. Boiled water must be filtered through a candle filter and kept covered. For poor households this is an expensive method of disinfection as commercial fuel costs are quite high.

Chlorination: While chlorine is used in large treatment processes, it is unsafe for domestic use. It should only be used if you suspect that the rainwater has been contaminated by animal faeces or there are signs of sickness after using rainwater. Although chlorine can kill a range of bacteria, it may not kill all viruses or cysts.

Its effectiveness depends on the correct dosage and the contact time – the time during which chlorine is present in the water till the time it is used (see Table 10.3: *The treatment efficiency of chlorine*). Chlorine dosage is based on the free residual chlorine (FRC) or chlorine that is available after it has combined with the contaminants to prevent recontamination. Ideally, dosage should allow for free chlorine at a concentration of 0.3-0.5 mg/l after 30 minutes. The general thumb rule is that an initial dose of 5 parts per million (5 mg/l) of chlorine will provide this residual.[1] If the stored water is in a tank, then chlorine must be mixed with water in a separate container before being added to the stored rainwater. After adding chlorine to the tank water, mix it well.[2]

Table 10.3: Common chlorine generating products and their chlorine content

Product	Strength	Remarks
High Test Hypochlorite (HTH) (calcium hypochlorite)	65% - 70%	Usually in granular form. Stable (2% active chlorine loss per year).
Chlorinated Lime, aka Bleaching Powder	30%	Usually in powder form. Not stable.
Household Bleach (sodium hypochlorite)	2.5% – 10%	Liquid form. Not stable; only use if manufactured recently (< 3 months), and stored away from heat and light.
Sodium Dichloro-Isocyanurate (NaDCC), used in products such as "Aquatabs".	50% - 60% as granules. 5mg to > 5 g active chlorine per tablet.	Usually in tablet form, also available in granular form. Tablets pre-dosed for water treatment. Very stable (shelf life 5 years).

Source: http://www.cawst.org/assets/File/chlorine.pdf, as viewed in March 2012

Direct sunlight: In India, solar radiation was used to disinfect water since ancient times. In modern times, water in clear plastic transparent bottles can be disinfected by solar radiation and heat. The efficiency of the disinfection will increase by painting one side of the bottle black to enable it to collect and radiate sun's heat. The water must be clear, the weather fine and the water cooled overnight before consumption.

SODIS: SODIS or Solar Water Disinfection was developed by scientists at the Swiss Federal Institute for Environmental Science and Technology (EAWAG) as a simple method of disinfecting water in tropical places where sunlight is available. It consists of three steps: (1) Settling or filtration to remove solid contaminants; (2) aerating filtered water in clear plastic bottles (PET bottles); (3) exposing filtered and aerated water to sunlight for a minimum of 5-6 hours. Both solar heat and radiation help to disinfect the water. This can be used for small volumes of low turbidity water. The system is highly effective against bacteria, viruses and protozoa.

Ultra-violet rays: Ultra-violet (UV) disinfection provides a concentrated UV radiation, commonly through a low pressure quartz mercury vapour lamp. The effectiveness of disinfection will depend on the electric power of the lamp, distance of water to the lamp and time of exposure. Water must be pre-treated and devoid of turbidity to be effective. Water flows around the lamp in a thin film. This is a clean method of treatment as no chemical additives are added and it does not leave behind any residual matter. There is also no change in taste or odour. However, the cost is relatively high and requires dependable electricity supply.

CASE STUDY

RAINWATER FOR DRINKING AND COOKING, RESIDENCE: R RAMANI, CHENNAI

R Ramani of Korattur, a suburb of to the north-west Chennai, once known for its lakes and ponds, has brought about a total change in the quality of the water from his open well.

The water in his open well was not potable as it was brackish and had high levels of iron. He implemented his RWH system in 1988 so that he could get water for drinking and cooking purposes. His system is a living example of how it is possible to meet all water needs for drinking and cooking in an urban situation, even for a residence that houses three families with 13 persons. He has not purchased even a drop of tanker water since he implemented rainwater harvesting. The 25-year old system is still functioning perfectly.

R RAMANI

Overhead tanks on roof with filtration tanks

WATER REQUIREMENTS

Mr. Ramani estimates that the annual drinking and cooking needs of the families that live in his bungalow to be 48,600 litres. His rooftop area is just 108 sq m and his storage capacity is also not very large – just 6,000 litres. Therefore, he has to replenish his storage at least eight times. Chennai receives rain from both the southwest and the northeast monsoons and additionally during cyclonic events. Thus it is possible to use rainwater for all potable purposes for the entire year. In fact, out of the total rainwater collected, only a third of the water is used for drinking and cooking and the remaining is used to recharge groundwater.


R RAMAN

Collection-cum-filtration tank


R RAMAN

Filtration system before use in kitchen

Drinking water

So, how does Ramani ensure that the water is potable? Water is collected in a collection-cum-filtration tank and after initial filtration is pumped to a separate section of a storage tank on the roof. Before entering this tank, water undergoes aeration and filtration through charcoal. This water goes to a set of filters made up of river sand, charcoal and pebbles. Then it is directed to a Aquaguard home filter after which this water is used for cooking and drinking.

Filtration stages for potable use

Stage 1	Stage 2	Stage 3	Stage 4
Settling, coarse mesh, pebbles of different sizes	Aeration, charcoal, pebbles	River sand, pebbles, charcoal, activated carbon	Aquaguard

Domestic use

The overflow from the collection tank on the roof and water from paved and unpaved areas is directed to a filtration tank and is then directed to three types of recharge structures: open well, a baby well and two recharge pits. Water from the open well is pumped to an overhead tank where it undergoes aeration and filtration through charcoal before being stored for use.

Filtration stages for domestic use

Stage 1	Stage 2	Stage 3	Stage 4
Settling, coarse mesh, pebbles of different sizes	Sand, pebbles, aeration in filtration tank	Recharge to groundwater	Aeration, charcoal, pebbles of water from well

TRANSFORMATION OF THE OPEN WELL WATER QUALITY

In the 1980s, the open well water was unsuitable for any use as it was high in iron, salty and brackish. As a result of regular recharging since 1988, by 2001, the open well water had become clear and potable. Today, even in summers or non-rainy days, this water is of very good quality. Water stored in the rainwater tank that was tested for microbiological contaminants was found to be completely free of faecal and total coliforms (see Table 10.4: *Microbiological test results*).

Table 10.4: Microbiological test results

Parameters	Units	Permissible	1994	1999	2012
pH		6.5 - 8.5	7	7.1	7.6
Turbidity	NTU	10	5	2	2
Total dissolved solids	mg/l	2,000	3,325	1,335	970
Total hardness (as $CaCO_3$)	mg/l	600	900	540	370
Total alkalinity (as $CaCO_3$)	mg/l	600	380	420	344
Iron (as Fe)	mg/l	0.3	NIL	trace	trace

Note: Sample of 12.5.94 was tested in S & S Industries & Enterprises, Madras; Sample of 9.4.99 was tested in the water analyst's lab of Chennai MetroWater; Sample of 6.1.2012 was tested in the water analyst's lab of Chennai MetroWater

System details

Total rooftop area: 108 sq m

Volume of storage tanks: 6,000 litres (3,500 overhead tank – civil) + 500 (Sintex) + 2,000 (GL sump)

Filter media: 1-2 inch size pebbles (at bottom), charcoal, coarse sand and half-sieved river sand (on top).

No of filter tanks: 5 (1 collection-cum-filtration tank; 2 Sintex tanks, 200 litres capacity each with charcoal, pebbles); 1 Sintex tank, 50 litre capacity each with charcoal, pebbles; 1 ground-level filtration tank)

Recharge structures: Open well, 2 recharge wells, 2 percolation pits

Cost: Rs 60,000 in the year 1988

Designed and implemented by

R Ramani, Chennai

3

SECTION

CASE STUDIES

The water team of Centre for Science and Environment has at least 25 years of engagement with rainwater harvesting in India. It all began with documenting the country's traditional water harvesting systems which culminated in the seminal publication *Dying Wisdom: Rise, fall and potential of India's rainwater harvesting systems*.

For this present study, the team has extensively travelled to different parts of the country to study and collect instances of modern rainwater harvesting systems. More than 80 case studies from the urban and peri-urban areas of the country were reviewed, and many of them feature in the pages that follow.

Surveys were carried out in different physiographic and geologic regions of India. Different approaches in regions of high and scanty rainfall were analysed.

A review of the systems in residential, institutional, industrial, commercial and slum areas was also done.

Studies of the existing traditional structures were also made to understand the usefulness of such decentralised systems. This section includes a look into bigger recharge structures like ponds and lakes as well

- Residences across the country are adopting rainwater harvesting (RWH). A family in Mysore has separate arrangements for municipal water and rainwater. A businessperson in Kolkata uses rainwater just to wash clothes. A government residence in Meghalaya uses rainwater for cleaning and gardening, thus saving municipal water

- Schools, hospitals and some religious bodies have been some of the greatest beneficiaries of RWH. With their bulk water requirements, stored rainwater adds to other supplies, such as municipal water. Even India's Presidential Estate has a RWH system

- Industries balance their groundwater intakes by recharging clean rainwater into the aquifer. Hero Motocorp in Haryana is going in for its fifth expansion of the RWH system

- RWH has been adopted in a wide variety of urban situations – from a *balwadi* in a slum to a sports complex

- Citizens' efforts have cleaned up lakes, which are in effect large recharge structures

- India has a rich tradition of traditional water harvesting systems which range from 200-year-old *tankas* in residences to large structures in forts. Some pre-Independence government buildings built by the British also have simple RWH structures

11

Residential

Independent residences

RESIDENCE OF H RAMESHA

BOGADI, MYSORE, KARNATAKA


H RAMESHA

The family of H Ramesha next to his 1,000-litre kitchen tank

H Ramesha, an engineer with the Kaveri Irrigation Corporation, built a rainwater harvesting (RWH) system in his home in 2003. With a family of four, he had to source quality water, and looked to the skies. He took into account that Mysore receives good rainfall for 8-9 months a year. The house has a 100-sq m roof which captures rainwater to be stored in three tanks. Just the kitchen tank of 1,000 litres suffices for all drinking and cooking needs. The water stored in the bathroom tank (of 5,000 litres) is used for washing hair and bathing while the underground sump (of 6,000 litres) is also used for bathing.

A 100 sq m roof area and just a 1,000-litre storage tank is sufficient for the drinking and cooking needs of this family of four members throughout the year

WHY: A CONCERN ABOUT QUALITY

Before this house was built, Ramesha lived in the same area – Bogadi – which is dependent on municipal water supply sourced from groundwater. The water was not potable being highly saline and having a high total dissolved solid (TDS) level. Vani, Ramesha's wife,

says: "Food cooked with the municipal supply gets discoloured and even spoilt overnight." The family found the water quality unsuitable even for bathing purposes. Thus, the impetus for collecting rainwater in their new house. In fact, they even have separate taps for municipal water and rainwater in the kitchen.


H RAMESHA

Scales being removed from the overhead tank which stores municipal water

Even in the new house, the tank that stores municipal water – which has high levels of TDS or total dissolved solids – collects a lot of scales (see Box: *High TDS in municipal water*). This is borne out by tests conducted by a vendor who installed a solar water heater in the new house.

High TDS in municipal water

A vendor who installed a solar water heater in the house tested the water from different sources and confirmed the high TDS levels in groundwater in the Bogadi area.

Water source	TDS levels (mg/l)	BIS limit (mg/l)
Borewell water	1,260	500
Cauvery river	460	
Rainwater	**80**	

Notes: TDS: total dissolved solids, BIS: Bureau of Indian Standards, mg/l: milligrams per litre
Source: H Ramesha

RAINWATER FOR DRINKING AND COOKING

Rainwater from the roof is directed to three storage tanks which includes the 1,000-litre kitchen tank which stores water for cooking and drinking. Municipal supply is used for bathing the three months in a year when it does not rain, and for cleaning and gardening round the year.

An elaborate system collects water for the kitchen tank. Rainwater is first directed to a filter tank. Before entry into the filter tank, a mesh filters out the coarse contaminants. The filter tank, in turn, leads to the

11

RESIDENTIAL

DIPANJAN BOSE

"Rice cooked with the harvested rainwater is soft and white as jasmine," says Vani, wife of Ramesha

System details
Roof area: 125 sq m
Storage systems: 3 tanks
Kitchen tank: 1,000 litres
Bathroom tank: 5,000 litres
Underground sump: 6,000 litres
Recharge system: 1
Recharge pit: 4 ft x 3 ft x 3 ft
Cost: Rs 12,000 (excluding cost of sump)
Year implemented: 2003

Designed and implemented by:
H Ramesha

large 1,000-litre capacity tank, placed next to the kitchen. From this tank, pipes bring water to the kitchen directly. Inside the kitchen, water is filtered through a branded drinking water purifier.

The RWH system has clearly proved beneficial. Ramesha has since added on to the rainwater harvesting capabilities in his home. An additional system to tap water from a sloped section of the roof, 25 sq m in area, has also been built. This water is directed to the underground sump.

IMPACT

Ramesha estimates that his total water demand annually is 1.8 lakh litres and he gets about 80,000 litres from rainwater. Thus, almost 50 per cent of his total water demand is met by rainwater.

RESIDENCE OF N ARUNACHALAM

KADACHENANDAL, MADURAI, TAMIL NADU

The residence of N Arunachalam is located in the Kadachenandal area, outside the municipal limits of Madurai. He is an engineer, once employed with the Public Health Engineering Department of the state. The four-member family uses rainwater for drinking and cooking throughout the year.

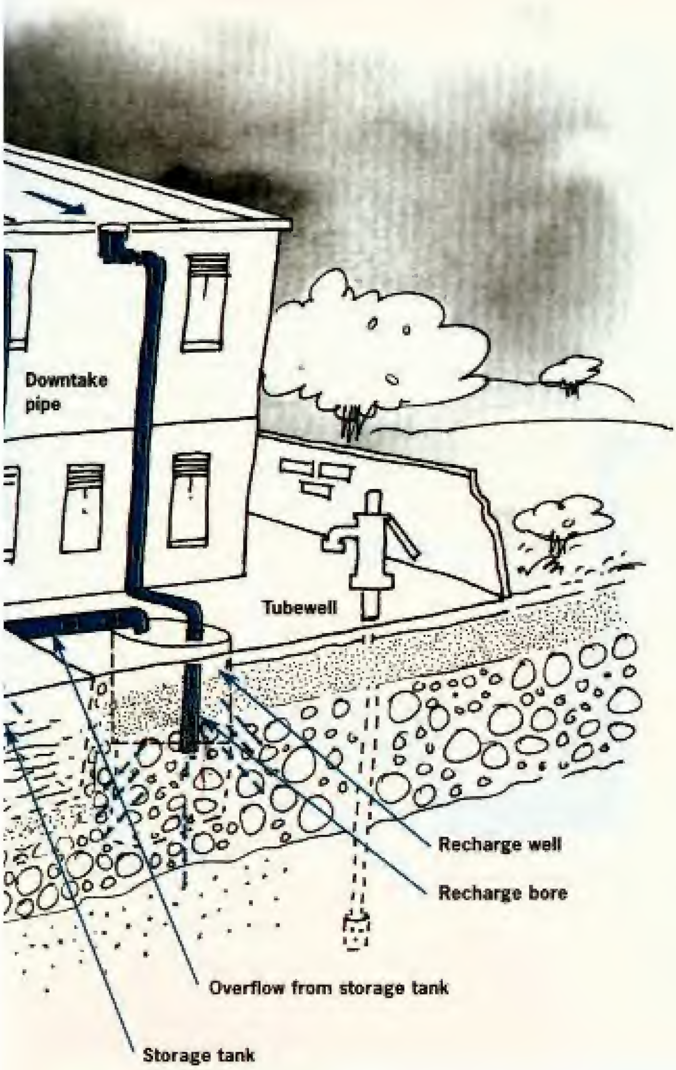
Rainwater is used for drinking and cooking for this family of four the year round. The municipality does not provide water and the area is entirely dependent on groundwater

WHY: LACK OF SUPPLY

The area where he lives is not serviced by municipal water supply. It is entirely dependant on groundwater, which is pumped up through a borewell. Arunachalam had the rainwater harvesting system built in 2005 to capture quality water.

RAINWATER FOR HOUSEHOLD NEEDS *AND* RECHARGE

The size of the roof is 174 sq m and water from the rooftop passes out through two outlets. One outlet leads to a collection chamber and the water is then directed to a filter tank placed on the first floor of the



System details
Roof area: 174 sq m
Storage system: 1 storage tank: 3.66 m x 1.22 m x 2.44 m (stores 10,895 litres)
Recharge system:
1 recharge pit (90 cm dia, 3 m depth)
Year implemented: 2006
Cost: Rs 44,000

Designed and implemented by
N Arunachalam

house below the collection chamber. It consists of four layers of filter media: pebbles – 20 cm, charcoal – 20 cm, sand mixed with charcoal in the ratio 1:1 – 20 cm and fine sand – 10 cm.

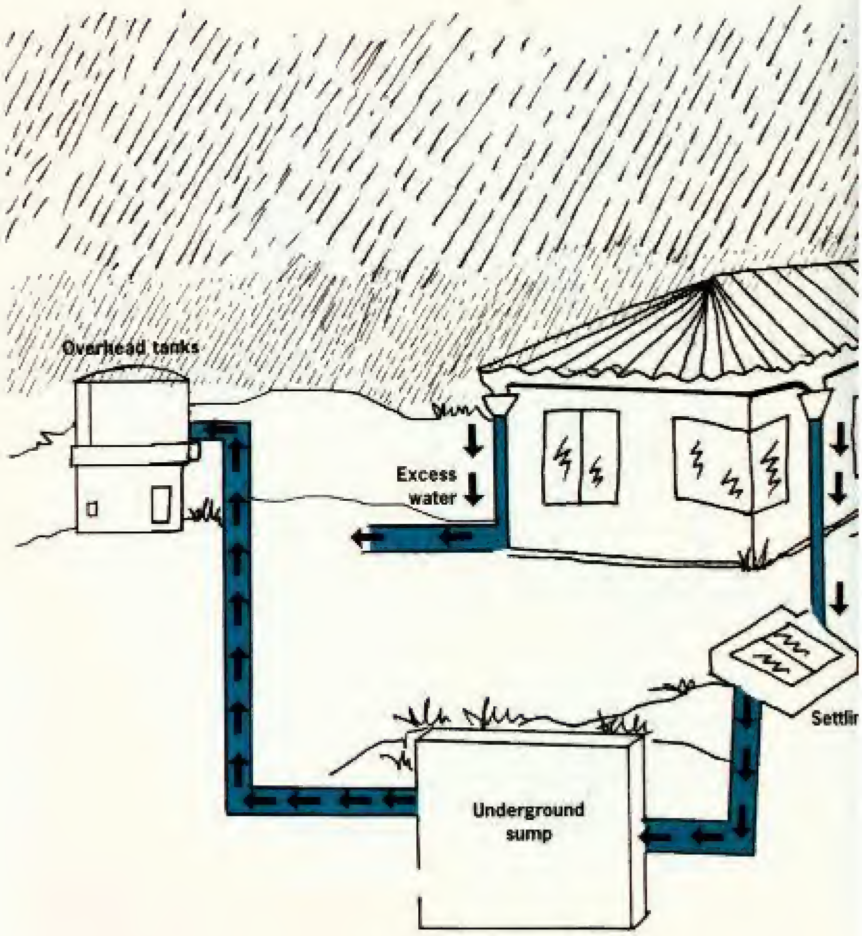
Filtered water is led to an underground sump of 10,895-litre capacity. This water is then pumped up to an overhead tank, which is mainly used for cooking and drinking. If there is excess water, then rainwater is used for mopping, car washing, among other chores. The overflow from the sump is directed to a recharge well. This water recharges the groundwater which is accessed through a tubewell at a distance of 2 m from the recharge well.

IMPACT

The family's monthly cooking and drinking water demand is about 600 litres. The underground sump collects enough water for the whole year.

RESIDENCE OF STEPHEN ALTER

LANDOUR, MUSSOORIE, UTTARAKHAND



Stephen Alter's cottage, Oakville, is perched on a hilltop in Landour, Mussoorie at a height of 2,187 m. It has a well designed rainwater harvesting system that was constructed in 1998.

WHY: TO AUGMENT MUNICIPAL SUPPLY

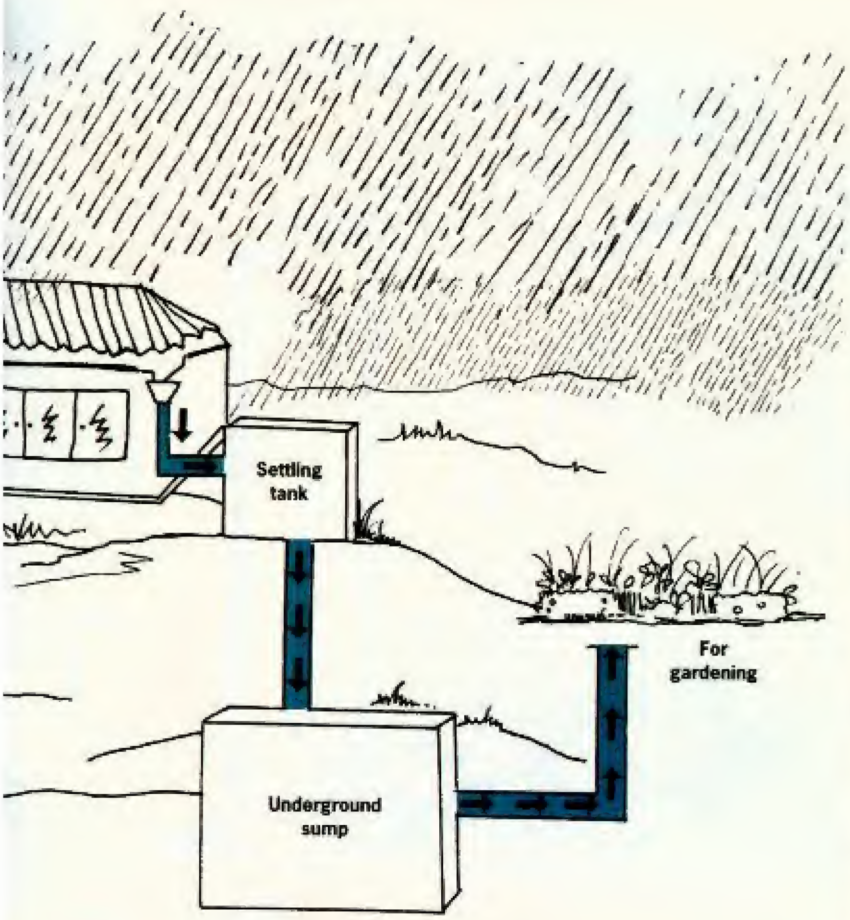
Rainwater supplements the erratic municipal supply, which comes once in two days. In summers, the supply comes only once in three or four days. Rainwater collected from the roof is stored in underground sumps and used in the toilets, bathrooms and for laundry, cleaning and gardening.

DUAL WATER COLLECTION SYSTEM

Rainwater is a reliable alternative to municipal water, which is not supplied regularly

Water flowing down the sloped galvanised iron roofs is collected in gutters and diverted to two water collection points. A system of manual valves allows the first day's rain to be diverted away from the system. From one collection point, rainwater is led to a settling tank of 1,000-litre capacity from where it passes into another sedimentation tank.

The rainwater then goes straight to the main sump, which has a capacity of 40,000 litres. There is a mesh at the entry point of the main tank to trap any debris or other impurities. The overflow of this sump



System details
Total roof area: 644 sq m
Roof area used for water harvesting = one-fourth of total roof area: 161 sq m
Storage system: 2 underground sumps (40,000 and 20,000-litre capacity)
Settling tanks: 2 (1,000 and 400-litre capacity)
Sedimentation tank: 2.5 ft x 2.5 ft x 2 ft
Cost: Rs 80,000
Year implemented: 1998

Designed and implemented by
Stephen Alter

passes downhill to recharge the underground water. This water is then pumped to an overhead tank of 500 litres.

At the second collection point rainwater is led to a settling tank of 400-litres capacity. This tank has two compartments. In the first compartment, some sedimentation takes place when the water flows in. After this the water passes to the adjacent compartment where further desiltation takes place. Ultimately, the rainwater is stored in another underground sump of 20,000 litres.

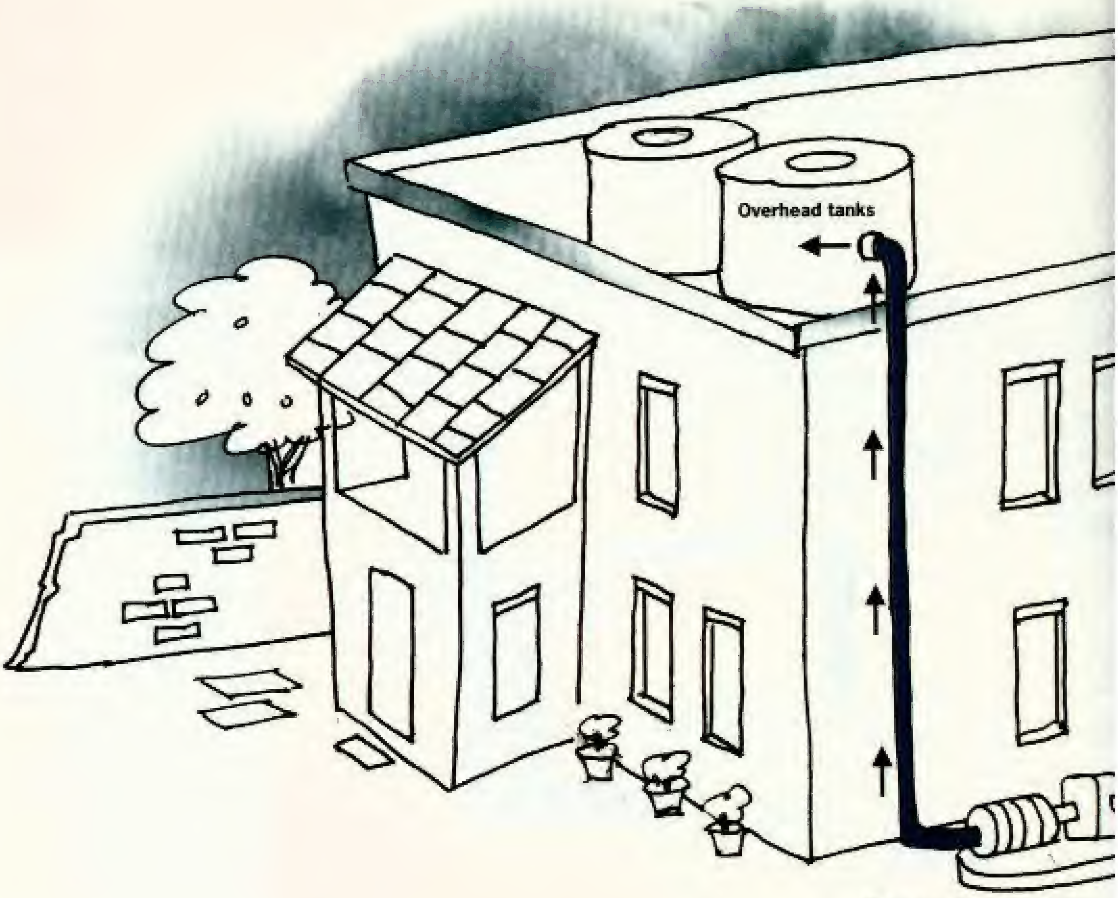
IMPACT

The amount of rainwater required in one day for the flush is 90 litres. The rainwater stored in the main sump is sufficient for one season.

The water from the second sump can also last one whole season. It is used for gardening in summers and acts as a back-up when there is no municipal supply. About 200 litres is used per day.

RESIDENCE OF O P SHARMA

INDORE, MADHYA PRADESH



The residence of late O P Sharma is located in the Pipliyakumar area of Indore. The rainwater harvesting system was built in 2000.

WHY: WATER CRISIS

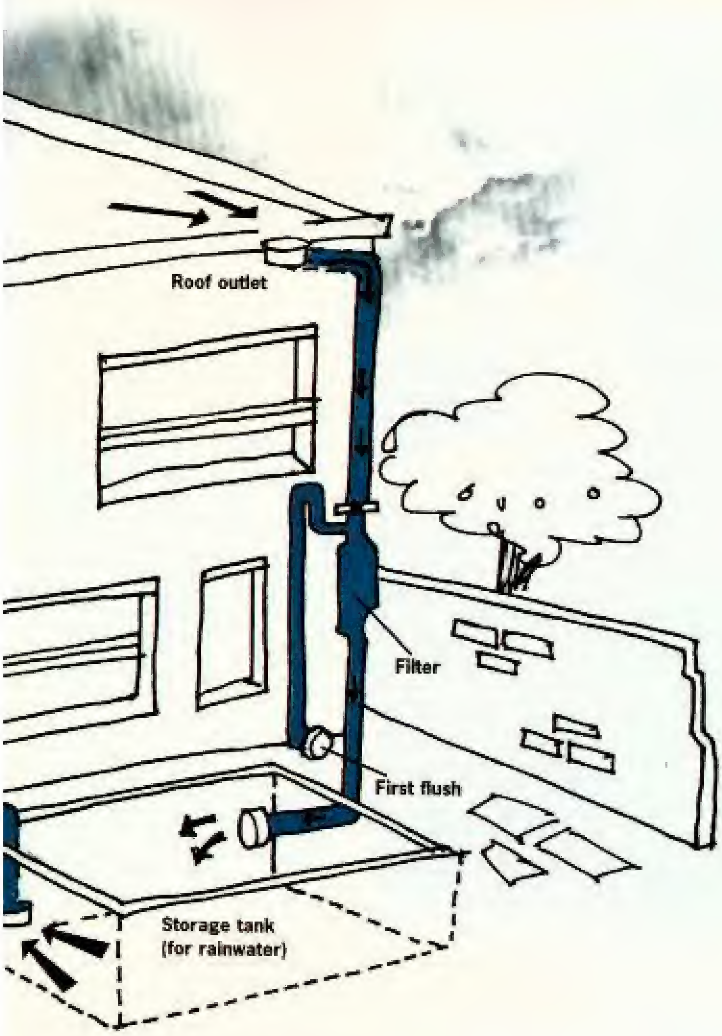
Indore is a city under the permanent throes of water scarcity. It was in the news way back in 1999 for this reason. The situation had not changed. In 2011 the authorities had to declare the entire district as water scarce.

Pipliyakumar lies within the city municipal limits, but there is no municipal water supply. The entire water supply of the area is sourced from groundwater. At the Sharma residence, water is pumped from a 122 m-deep tubewell.

DEDICATED MAINTENANCE, INTELLIGENT USE

The area of his rooftop is 120 sq m and collected water is directed to the downtake pipe. A filter has been installed in the downtake pipe itself. The filter contains coal, sand and gravel in layers and the filtered water is taken to the underground sump.

The total daily water demand for two persons is about 300 litres for



System details
Total rooftop area:
120 sq m
Volume of storage tank:
100,000 litres
Cost: Rs 2.5 lakh
Year implemented: 2000

Designed and implemented by
O P Sharma

Rainwater harvesting has arrested the decline of groundwater levels. The Sharma household does not need to buy water even in summer. They balance water usage from the tubewell and underground tank

drinking, cooking, washing and cleaning. Rainwater is passed through a standard domestic water filtration system before drinking.

The family maintains the system well. The rooftop is kept very clean throughout the year. Every year before the rains, the underground sump is also cleaned thoroughly.

IMPACT

The family uses water intelligently. They do not need to buy water supplied by private tankers even in summer. They balance the use of water from the tubewell and the underground tank so that the stored rainwater of 100,000 litres lasts for the non-rainy months. In contrast, the neighbourhood is largely dependent on these tankers.

DEPUTY CHIEF MINISTER'S RESIDENCE

BARIK POINT, SHILLONG, MEGHALAYA

The residence of Meghalaya's deputy chief minister boasts of a simple and user-friendly rainwater harvesting structure.

WHY: DRY SUMMERS

Although the building receives municipal supply, there are water shortages during the summer months. Meghalaya receives nearly 2,300 mm of annual rainfall spread over nearly seven months in the year. The rugged terrain limits the possibility of groundwater storage. Storing rainwater is, therefore, a good option. In this residence, stored rainwater is used for gardening and cleaning.

System details
Total rooftop area: 186.2 sq m
Storage system: 3 tanks (each, 1,000 litres)
Year implemented: 2001

Designed and implemented by
WAPCOS Ltd, New Delhi and Central Ground Water Board, Shillong

OPTIMAL USE OF STORAGE TANKS

The residence does not have a very large roof area, just about 186 sq m, but the storage tanks are strategically placed for optimal use. Next to the kitchen, there is one storage tank that provides water for use in the kitchen. It is used for washing and cleaning. Two other tanks are close to the lawn and garden areas and are used for car wash and gardening. The tanks are provided with taps for easy access.

IMPACT

Rainwater is used for all cleaning and gardening purposes, thus saving on treated municipal supply.

11

RESIDENTIAL

RESIDENCE OF N K KANODIA

ALIPUR, KOLKATA, WEST BENGAL

The underground sump lies below the driveway

System details
Total catchment area: 300 sq m
Storage system: 1 underground sump (70,000 litres)
Cost: Rs. 2.5 lakh
Year implemented: 2006

Designed by *Ranjit Gupta, Interdesign, Kolkata*
Implemented by *N K Kanodia*

N K Kanodia, a Kolkata-based businessperson, uses rainwater round the year for laundry. Municipal water is used for all other purposes.

WHY: FOR LAUNDRY

In Kolkata, municipal water supply is generally adequate. But, clothes washed with this water tend to 'yellow', the colours fade and the fabric thickens.

HOW IS THE WATER COLLECTED

Kanodia uses his 300 sq m rooftop to collect rainwater. This is channeled to collection chambers and after passing through a metallic sieve, collected in an RCC (reinforced cement concrete) storage tank constructed underground. The capacity of the storage tank is 70,000 litres.

Rainwater is exclusively used for laundry throughout the year. It saves clothes from turning 'yellow' from municipal water

IMPACT

The Kanodia residence uses, on an average, 200 litres per day for laundry. The stored rainwater is enough for his laundry needs. Kanodia says the clothes remain bright and crisp.

Colonies, apartment buildings and housing societies

RESIDENTIAL COLONY

NIZAMUDDIN (EAST), NEW DELHI

Nizamuddin (East), located off Mathura Road, consists of 50 large and 200 small and medium-sized plots. It also has at least 32 public parks. The area faced a waterlogging problem. The residents decided to do something about it.

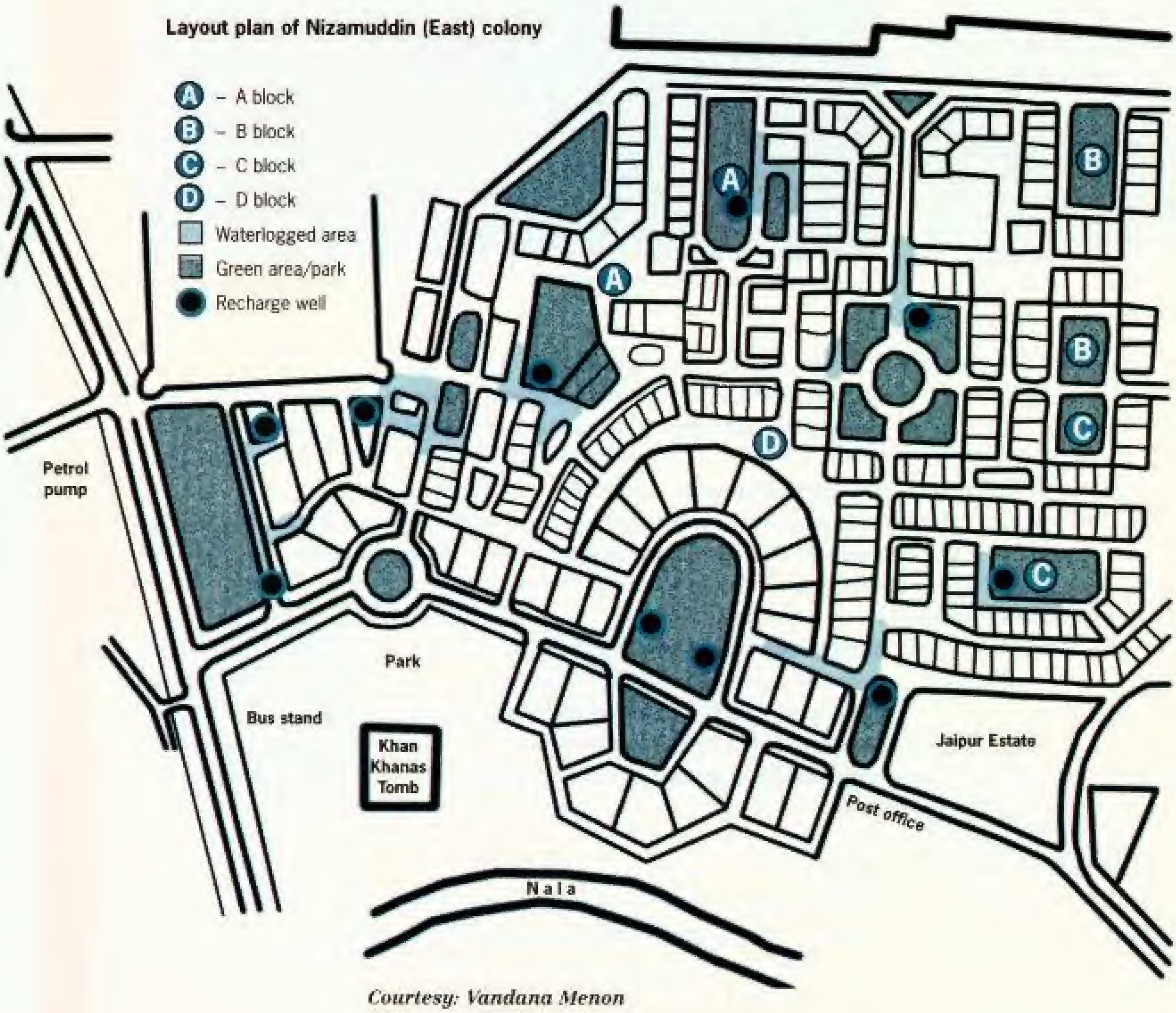
WHY: LOW-LYING AREAS WATERLOGGED

The colony is situated close to the Yamuna flood plains and the sub-soil is a mix of sandy and clayey soils. Thus, natural recharge is difficult. The waterlogging took place in some low-lying areas in the colony. During heavy downpours, the water level used to come up to the knees.

RAINWATER FROM STORMWATER DRAINS

In early 2002, residents were mobilised by Vandana Menon, an architect and resident, to build rainwater harvesting systems. Being a small colony with a fairly large number of tenanted properties, the Resident Welfare Association could not collect a large amount of funds.

Layout plan of Nizamuddin (East) colony



Courtesy: Vandana Menon

Rainwater in the stormwater drains was tapped to recharge groundwater. This was an effective antidote to waterlogging

A waterlogged lane in the colony

Harvesting the rainwater from the stormwater drain has stopped flooding

System details
Total rooftop and surface area: 2.01 lakh sq m
Collection chambers (1 per recharge structure): 0.45 m x 0.45 m x 0.5 m
Recharge pits (11): 1 m x 1 m x 2 m
Recharge bore: 10 m deep with 150 mm dia
Cost: Rs 1.79 lakh

Designed by *Centre for Science and Environment, New Delhi*
Implemented by *Resident Welfare Association, Nizamuddin (East)*

Nevertheless, the idea was put into action. The plan was to use rainwater to recharge groundwater and also control the waterlogging.

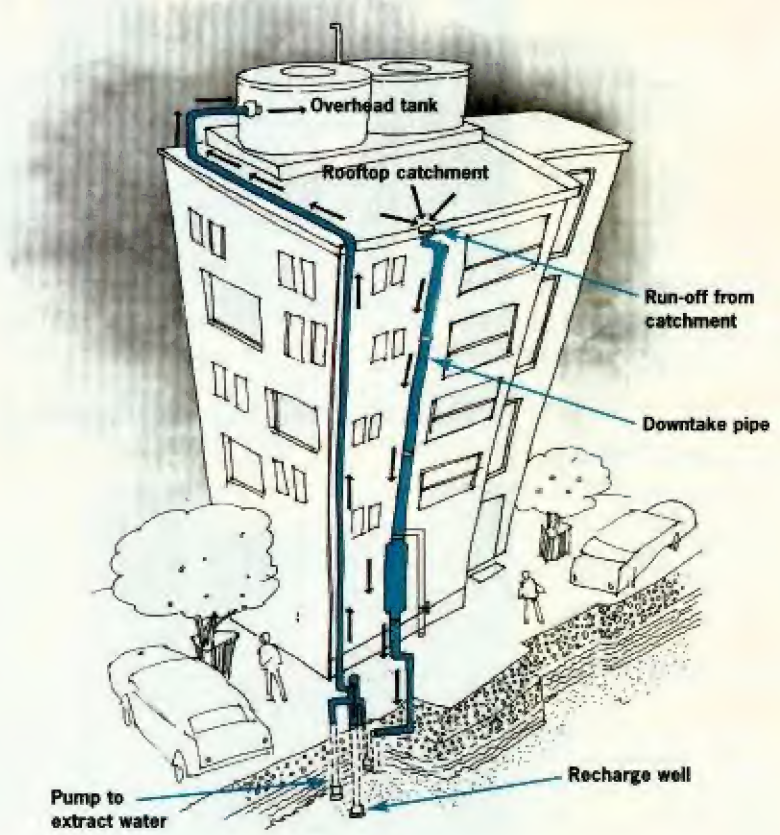
Rainwater flowing through the stormwater drains was harnessed – it was first led to desilting chambers and then to recharge structures. The recharge wells with filter media were laid in the numerous parks within the colony. A total of 11 recharge structures were constructed and two old structures were repaired at a cost of Rs 1.79 lakh.

IMPACT

The system was completed in 2004 and the residents could soon see the results. Waterlogging has reduced greatly in the colony.

MULTI-STOREYED APARTMENTS

PRIYADARSHINI HEIGHTS, BHOPAL, MADHYA PRADESH



Priyadarshini Heights, a block of 16 apartments in Gulmohar Colony, Bhopal, was the first to install a rainwater harvesting system in the area to recharge their borewells and end tanker supplies.

WHY: NO MUNICIPAL SUPPLY

The colony was not connected to municipal supply till 2009. The only source was groundwater. Tankers supplemented the decreased water availability from the borewell during peak summer. The Association for Motivation of Biosphere and Environmental Revolution (AMBER) society, a local NGO working on water conservation, convinced the residents that rainwater harvesting would solve their problem.

RECHARGING THE BOREWELL

In 2002, a rainwater harvesting system was built to recharge the in-use borewell. As the area lies on Deccan basaltic rock, drilling a recharge well would have been expensive. Thus, the decision to recharge the borewell.

Rainwater from the roof is diverted to the borewell through downtake pipes, which are joined to a single pipe. Before reaching the recharge well, water is filtered through an online AMBER filter. The filter consists of sand, gravel and charcoal and pebbles.

IMPACT

The in-use borewell has been successfully recharged. The water level has improved by nearly 10 m – from 30 m in 2002 to 20 m in 2011. The other, defunct borewell has also started functioning now.

System details
Total rooftop area: 540 sq m
Cost in 2002 (pipes and filter): Rs 6,500

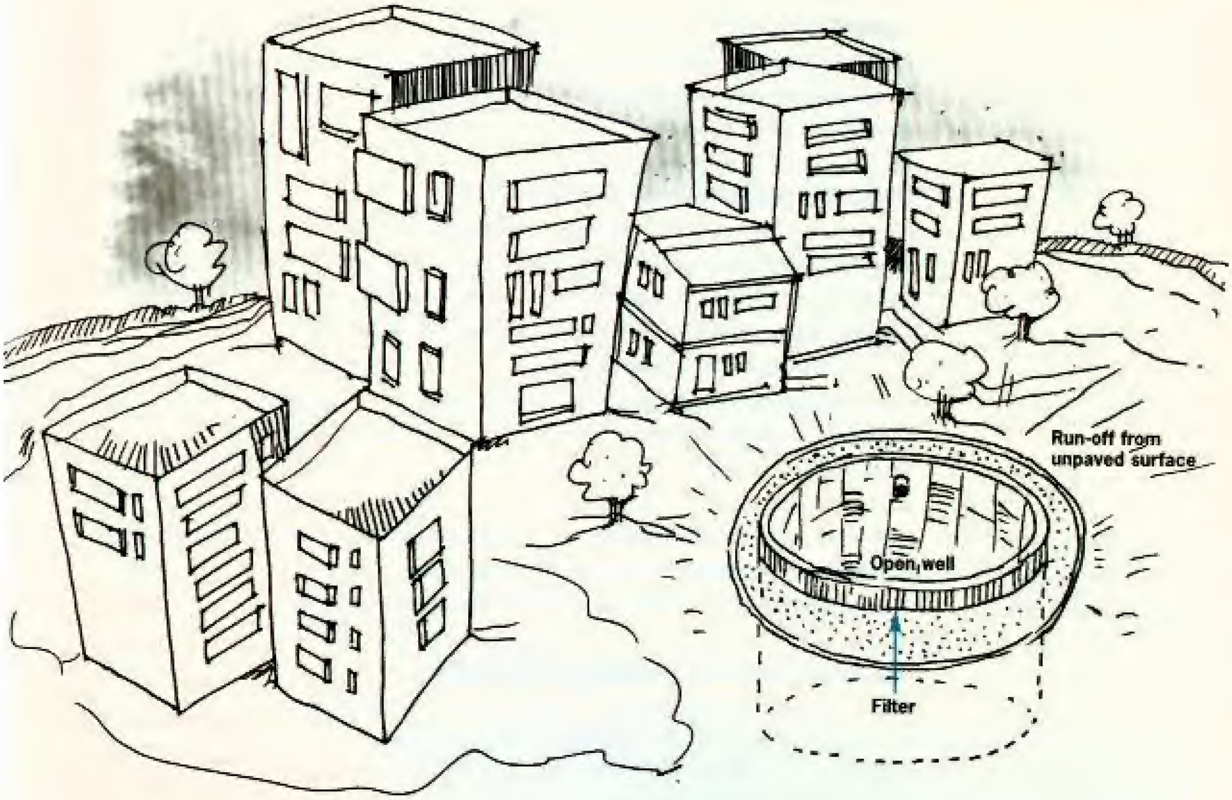
Designed by *Brijesh Namdeo, AMBER, Bhopal*
Implemented by *Priyadarshini Heights Residents' Association*

HOUSING SOCIETY

11

RESIDENTIAL

BIMANAGAR COOPERATIVE HOUSING SOCIETY, AHMEDABAD, GUJARAT



The Bimanagar Cooperative Society (BCS) comprises of 54 tenement blocks with a total of 324 residential units. A rainwater harvesting system was put in place in 2002, when the Ahmedabad Urban Development Authority (AUDA) made it compulsory for all buildings of over 1,500 sq m to install these systems.

WHY: DRY BOREWELLS

The colony faced a water crisis due to dry borewells and erratic water supply from the municipality.

RECHARGE THROUGH PERCOLATION WELL

Rainwater from the building rooftop, roads and open ground is diverted to a percolation well, which has been constructed in a low-lying area of the park. The rainwater is filtered through a bed of pebbles and sand has been laid on the periphery of the well for filtration of the rainwater before it enters the well. The well is constructed with honey-combed brickwork to facilitate movement of rainwater from well to the ground.

IMPACT

In this drought-prone area, the quantity and quality of groundwater has improved after recharge through a percolation well.

System details
Total rooftop area: 16,635 sq m
Dimensions of the well: 6 m dia, 10.7 m depth
Cost: Rs 1.6 lakh
Year implemented: 2002

Designed by
PRAVAH & Centre for Integrated Development, Ahmedabad
Implemented by
Bimanagar Cooperative Housing Society

RESIDENTIAL COLONY

RAINBOW DRIVE COLONY, BENGALURU, KARNATAKA

Rainbow Drive in Sarjapur Road, Bengaluru is one of the newly developed colonies on the city's outskirts. This colony has thought beyond rainwater harvesting. Its residents have optimised on the use of rainwater, through recharge, discounts on water bills and a water tariff system that accounts for costs of treatment, supply and sewage treatment.

WHY: DECLINING GROUNDWATER YIELDS

The colony does not receive water supply from the Bangalore Water Supply and Sewerage Board (BWSSB) and depends on groundwater. Water used to be extracted from six borewells located in the colony, which had been sunk in 2003 when the colony came up.

As the number of houses in the colony increased – they are now more than 200 – groundwater yields declined drastically. The colony faced one of its worst crises in 2007 when the Residents' Welfare Association realised that it was one step away from depending on water tankers, if the last borewell dried up. This forced some of the office bearers of the Association to think about rainwater harvesting for long-term water security; they initiated a colony-wide rainwater harvesting system using the stormwater drain network.

RECHARGE WELLS IN STORMWATER DRAINS

The residents moved fast. By end 2008, the colony had 54 recharge wells installed in the society's stormwater drains and on private plots.


BIOME ENVIRONMENTAL SOLUTIONS

A recharge well in a stormwater drain. The jelly stones desilt the water before it enters the well

System details
Total area: 137,593 sq m (34 acres)
Area of unpaved surfaces (15 per cent of total area): 20,639 sq m
Number of houses: 240
Recharge wells (20 in stormwater drains, 51 in homes): 71 (3 ft dia, 20 ft deep)
Volume of wells: 2.84 lakh litres

Designed by
Biome Environmental Solutions Pvt Ltd, Bengaluru
Implemented by
Rainbow Drive Residents' Welfare Association

The system incorporates a detailed filtration process. As a first step, water passes through a *silt trap* made in the stormwater drain. This ensures that the silt settles down and leaves the water on top fairly silt free. *Soak away pipes* are provided at the bottom of the silt traps to ensure that water doesn't collect in the silt trap after the rains, thereby becoming a breeding ground for mosquitoes.

The next feature is a *leaf trap*, which is a concrete grate that prevents leaves or plastic bags from entering the recharge well. Then the water runs through a *check dam* consisting of a small brick masonry or concrete wall spanning the drain and preceded by a mound of 40 mm *jelly stones* that inclines 4 feet (1.2 m) towards the well. The jelly stones remove more silt from the water before it enters the well. PVC pipes covered with nylon mesh at the intake points are built into the check dam wall, leading directly into the well.

In the event of heavy rainfall, a hole covered by a *netlon mesh* that exists on top of the RCC slab covering the well, allows water to enter from the top of the well. If the water entering the well exceeds its capacity, there is an overflow pipe that allows the excess water back into the stormwater drain leading downstream.

Stormwater drain network was harnessed to initiate a rainwater harvesting system across the colony

IMPACT

The wells have a total volume of 2.16 lakh litres and hence can recharge multiples of 2.16 lakh litres at the time of each rainfall. From a situation where only one of six borewells was yielding water, today water is pumped out from three borewells which have enough water even in summer months.

Quality water from sewage

In 2011, the colony residents approved a plan to set up a new sewage treatment plant (STP) based on soil biotechnology, developed at IIT-Mumbai. This technology will provide river quality water for reuse as opposed to conventional methods which treat water for disposal. The colony intends to supply this water for non-potable use to all residents as well as sell it for use in constructions to recover the cost of the STP.

Innovative tariff to discourage wastage of water

To enforce conservation, the residents of Rainbow Drive have introduced a tariff system that charges users for the true cost of water. Charges are based on cost of treatment, supply and sewage treatment. The slab-based tariff discourages wastage. Private borewells have also been banned. An incentive is also in place – residents with recharge systems get a discount of Rs 100 on their water bills.

Table: Slab-based water tariff

WATER CONSUMPTION LEVEL	TARIFF (Rs/kl)
First 10,000 litres (0-10 kl)	10
Next 10,000 litres (10-20 kl)	15
Next 10,000 litres (20-30 kl)	25
Next 10,000 litres (30-40 kl)	40
Above 40 kl	60

Source: Rainbow Drive Residents' Welfare Association

RESIDENTIAL COLONY

DEFENCE COLONY, NEW DELHI

DEBASIS TUDU / CSE

Stormwater drains run on both sides of the road in C-Block, Defence Colony

System details
Total rooftop: 26,087 sq m
Dimension of recharge well: 1.5 m x 1 m x 2 m
Dimension of recharge bore: 150 mm dia, 17 m deep
Cost in 2003: Rs 2.58 lakh

Designed by
Centre for Science and Environment, New Delhi
Implemented by
Defence Colony, C-Block, Residents' Welfare Association

In Defence Colony, one of the oldest residential areas in south Delhi, developed in the 1950s, rainwater harvesting has arrested groundwater decline.

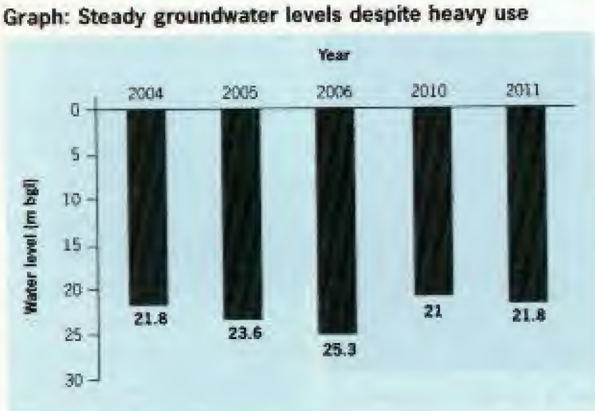
WHY: GROUNDWATER LEVEL LOWERS IN SUMMER

The colony has been using groundwater to supplement municipal water supply, resulting in lowering of the water table. The water table especially goes down in the summer months. It is because of this that the residents' welfare association took a decision in 2003 to harvest rainwater.

ROOFTOPS TO STORMWATER DRAINS TO RECHARGE WELLS

Rainwater from the rooftops and the paved surfaces of the colony is diverted to the stormwater drains that run on both sides of the two main lanes, Chakarvarty Vithi and Chandan Vithi that run through C-Block, Defence Colony. Nineteen recharge wells have been constructed in the main and back lanes of Chakarvarty Vithi and Chandan Vithi. The recharge wells are filled with boulders, pebbles and coarse sand so that filtered water enters the recharge bores placed in the wells. A baffle wall has been constructed in the stormwater drain to slow down water flow and allow sediments to settle.

Graph: Steady groundwater levels despite heavy use



Note: m bgl: metres below ground level
Source: Centre for Science and Environment, New Delhi

IMPACT

Although there has been a steady use of groundwater by the colony residents, rainwater harvesting has enabled groundwater levels to be maintained from 2004 through 2011 (see Graph: *Steady groundwater levels*). Citizens say that previously defunct borewells or those with very low yield of water have started yielding good amount of water.

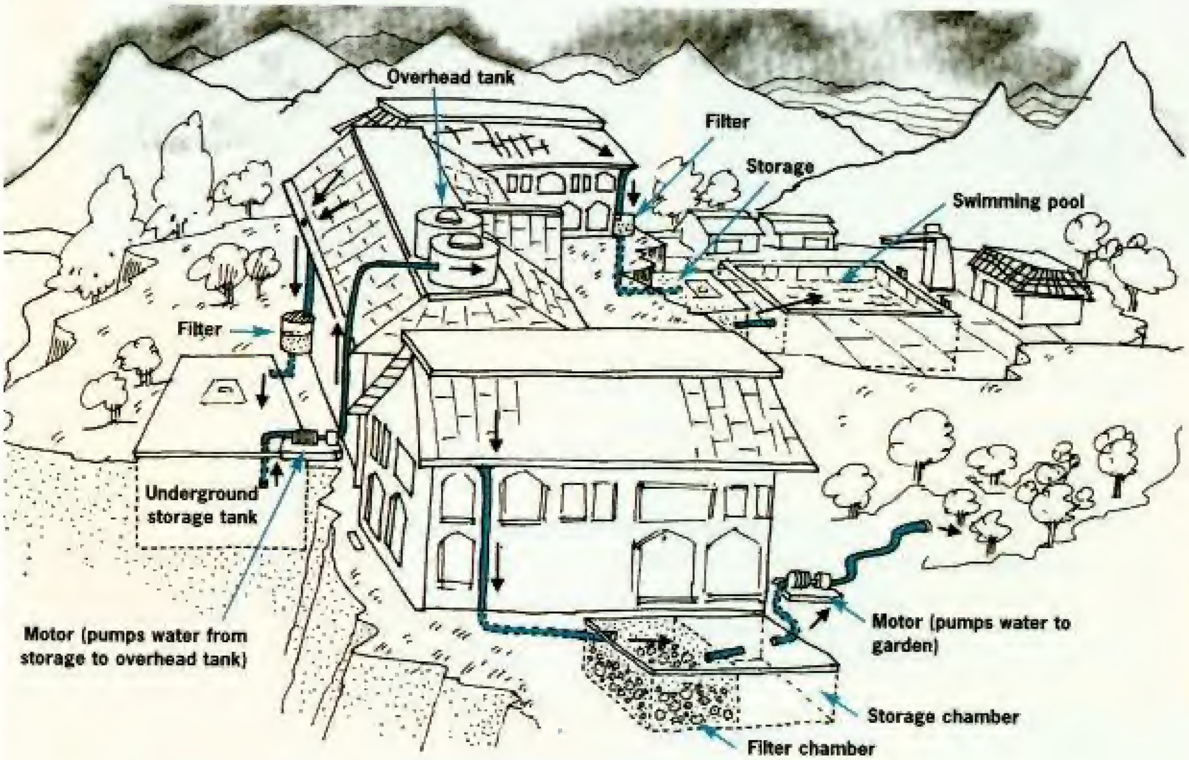
12

Institutional

Schools

BISHOP COTTON SCHOOL

SHIMLA, HIMACHAL PRADESH



Bishop Cotton, located within the municipal limits of the hill station of Shimla, is one of the oldest boarding schools in Asia. The school harvests rainwater for drinking during the rainy season. In other seasons, rainwater covers the demand for flushing, laundry and the swimming pool.

The stored water is used for laundry, flushing and gardening, thereby saving municipal supply for drinking and cooking purposes

WHY: SHORTAGE OF WATER IN SUMMER

As this is a residential school with over 500 students, its water demand is substantial: the daily requirement is about 80,000 litres. In recent years, in summer, there has been a huge shortage of water in the school campus. The municipal water supply is supplemented by groundwater pumped through 4 borewells. Each year the school authority had to increase the depth of the borewells, with groundwater having fallen to a depth of 97 metres below ground level (m bgl).

During the monsoons, municipal water becomes muddy and rainwater is used for drinking, after filtration, the school having installed a state-of-the-art filter for the purpose.

Rainwater harvesting filter

Underground storage tank

Table: Catchment areas in the school

Name of the building	Roof area (sq m)	Capacity of the tank (litres)
Main dormitory and dining hall	301.50	185,000
Activity Centre	237.00	60,000
Remove Building (Lewis Block)	928.80	60,000
Headmaster's Lodge	400.00	250,000
Total	1,867.30	555,000

Source: Bishop Cotton School, Shimla

System details
Total rooftop area:
1,867.30 sq m
Total storage capacity:
555,000 litres
Filtration drums:
1.5 ft to 2 ft dia
Filtration tanks:
1.5 ft x 1.5 ft x 1.5 ft
Filter media layers:
stone: 0.4-0.15 cm; grits: 0.1-0.15 cm; chips: 0.15 cm; sand: 0.15 cm
Total cost (2000-2002):
Rs 16.65 lakh

Designed and implemented by *Bishop Cotton School*

COLLECT CLEAN WATER

The school uses the roofs of the main school building, the Activity Centre, the Remove Building and the Headmaster's Lodge to collect rain. For every roof area, a filtration tank has been designed to ensure that clean water enters the underground storage tanks, which have a total storage capacity of 555,000 litres (see Table: *Catchment areas in the school*).

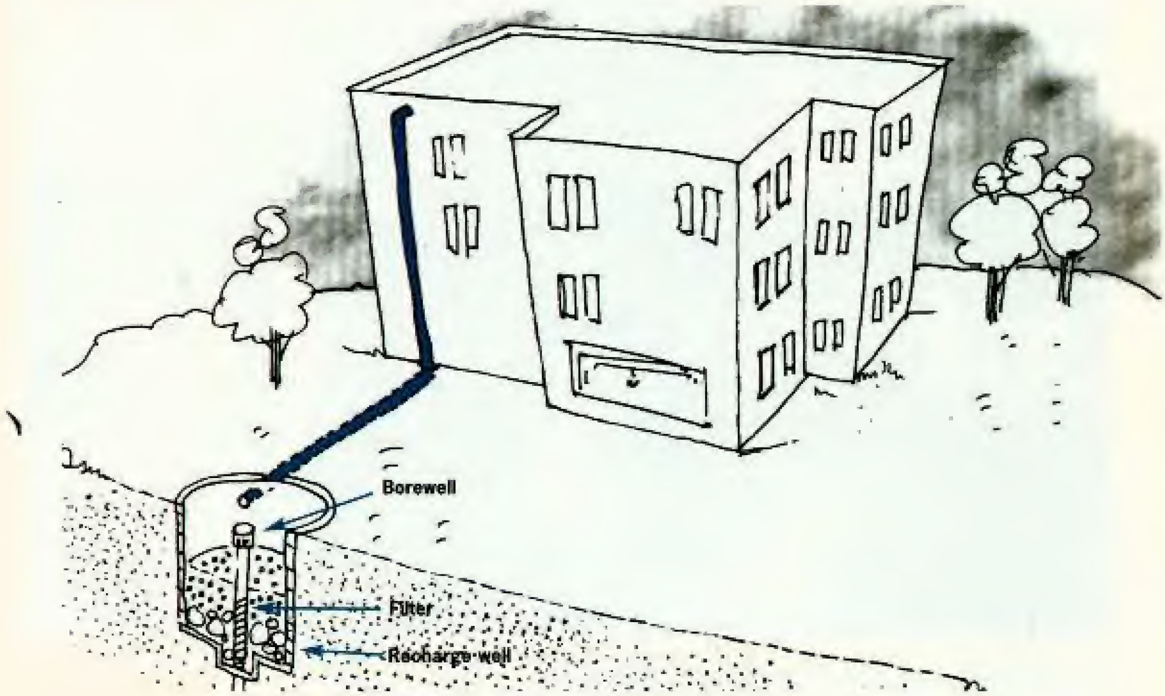
Maintenance work is undertaken in May and October when the filter materials are washed thoroughly. The tanks and the catchments are also cleaned during this time. The total expenditure on maintenance comes to Rs 10,000 per year.

IMPACT

The stored water is used for laundry, flushing and gardening, thereby saving municipal supply for drinking and cooking purposes.

SISHYA

CHENNAI, TAMIL NADU



At Sishya, rainwater harvesting has been used to recharge groundwater. In its fortieth year, this school is run by the Kit Thomas Educational Society, in Adyar, Chennai.

WHY: RESIDENTS DEPEND ON GROUNDWATER

The residents of the area depend heavily on groundwater for potable and non-potable purposes. Since the area is located on coastal alluvium soil which is porous and permeable, it has good potential of holding groundwater and therefore recharging the coastal aquifer was the best option.

TWO RECHARGE PITS AND ONE RECHARGE WELL

The school has a total area of 4.5 acres (1.8 hectares) and a rooftop area of 6,000 sq m. Rooftop rainwater is directed down through a downtake pipe and recharges the groundwater in the campus. There are two soak pits and one large recharge well. The pits are filled with filter media such as stones and brickbats (broken bricks).

The water recharging structures are cleaned annually before the onset of the rains. The washed filter media is replaced.

IMPACT

The school authorities have noticed substantial improvement in water level. Earlier, the school used to buy 24,000 litres at a cost of Rs 1,500 per week. They have now stopped purchasing water, saving approximately Rs 60,000 annually.

Although water quality has not been tested, school authorities say that salinity has decreased to a great extent. Groundwater is now used in the washbasins for mouth rinsing. This was not possible before.

There has also been a great deal of improvement in waterlogging, the most visible benefit of rainwater harvesting.

System details
Total rooftop area: 6,000 sq m
Dimension of the recharge pipe: 200 mm dia, 1.5 m deep
Dimensions of recharge well: 2.5 m dia, 1.5 m deep
Cost: Rs 65,000
Year implemented: 2006

Designed and implemented by
Kit Thomas Educational Society

KERALA PUBLIC SCHOOL

MANGO, JAMSHEDPUR, JHARKHAND

SUSHMITA SENGUPTA / CSE

Moushumi Roy, teacher in charge of Eco Club (left) and Vijayam Kartha, principal of the school in front of the open well which has been recharged

Kerala Public School is a three-time winner of the Centre for Science and Environment's *Gobar Times*-Green School Awards for its efforts in rainwater harvesting. The practice has brought back water in a defunct open well in the school premises.

WHY: WATER SCARCITY ACUTE WITH DEVELOPMENT

The Mango area is known for its water scarcity. In recent years, it has become acute, with a spurt of residential development, and more borewells being sunk to source water. Yet, as much of Jamshedpur sits atop hard rock and is unsuitable for groundwater recharge, most borewells go dry in Mango every 3-4 years. Municipal water supply is erratic, often supplied every 3-4 days and that too for a few hours.

The school does not receive any municipal supply and has to depend on groundwater for all its uses. The daily water demand of the school is 13,000 litres for drinking, flushing and gardening.

CLEAN FILTERED RAINWATER RECHARGES WELL

The school uses its rooftop measuring 250 sq m to collect rainwater which is diverted to two collection chambers and then to a sedimentation tank. After this, the water is led to a filtration tank filled with charcoal, boulders and brickbats. The clean water coming out of this tank recharges the 15 m deep well.

IMPACT

Water levels have improved since 2005, when water harvesting was initiated. The well provides water for all non-potable uses of the school. The yield of the borewells in neighbouring areas has also improved, says Mousumi Roy, who is in charge of the Eco Club in the school.

System details
Total rooftop area:
250.8 sq m
Collection tank:
1 ft x 1 ft x 1 ft
Filtration tank:
2.8 m x 4.5 m x 1 m
Sedimentation tank:
2.8 m x 4.5 m x 1 m
Cost: Rs 48,000
Year implemented: 2005

Designed by *Environment Division, Tata Steel*
Implemented by *Kerala Public School, Mango*

JAMNABAI NARSEE SCHOOL

MUMBAI, MAHARASHTRA

At Jamnabai Narsee, a private school run by the Narsee Monji Foundation in Juhu, Mumbai, the rainwater harvesting system was set up in 2006. During the rainy season, stored rainwater supplements municipal water supply and reduces dependance on tanker water.

WHY: MUNICIPAL SUPPLY IS INADEQUATE

The municipal supply is the primary source of water for the school, but quite inadequate in context of demand. The school has to buy water supplied through tankers regularly. Nearly 80,000 litres of water is used every day, of which nearly 50 per cent (40,000 litres) is used for flushing.

RAINWATER STORED, OVERFLOW RECHARGED

Rainwater from the rooftop of one of its buildings is filtered and stored in two underground sumps with a total capacity of 1 lakh litres. Overflow from the storage sumps is used to recharge the groundwater through a recharge well.

IMPACT

During the rainy season, stored rainwater is used for flushing. The school saves nearly Rs 75,000 every year by reducing the total number of tankers.

System details
Average annual rainfall in Mumbai: 2,422.1 mm
Total roof area: 1,858.74 sq m
Roof area catchment for rainwater harvesting: 325.16 sq m (3,500 sq feet)
No of storage tanks: 2
Storage capacity: 100,000 litres
Recharge well: 6 inch (152.4 mm) dia bore, 20 feet (6.096 m) deep
Cost: Rs 4 lakh
Year implemented: 2006

Designed by *U M Paranjpe, Jalvardhini Pratishthan*
Implemented by *Jamnabai Narsee School*

SALAHUDDIN SAIPHY / CSE

Mouth of underground sump (foreground). Two more can be seen in the background

JAL BHAWAN

JUNAGADH, GUJARAT

The Jal Bhawan in Junagadh is a government-owned building that houses offices such as the Gujarat Water Supply and Sanitation Board. Harvested rainwater is used only for drinking purposes by the staff throughout the year.

WHY: BAD QUALITY GROUNDWATER

During the dry season, groundwater becomes unfit for drinking. The total dissolved solid (TDS) count is on the higher side – between 1,000 and 1,200 parts per million (ppm) The groundwater levels also go down.

Till the rainwater harvesting system was erected, the drinking water needs of the Jal Bhawan staff were met by groundwater, with a RO or reverse osmosis plant installed to treat it.

FIRST FLUSH DIVERTED AND CLEAN WATER COLLECTED

Rainwater from the roof of the building is diverted to an underground sump with a capacity of 100,000 litres. At first, the water is filtered in a tank containing sand and pebbles. The first flush of rain is diverted into the stormwater drains and cleaner water is collected in the underground tank.

Water from the sump is pumped overhead into a 500-litre tank and used for potable purposes. Chlorine tablets and bleaching powder are added to the stored water before consumption. Water is tested regularly and the rainwater quality is found to be well within permissible limits of all parameters (see Table: *Water quality of the tank*). The tank is cleaned regularly.

Rainwater from the roofs of the two inspection bungalows in the same compound as Jal Bhawan, a store and garage, is also diverted to a recharge well.

IMPACT

This stored rainwater is used by 150 staff members throughout the year (270 working days) for drinking only.

System details
Total area: 1,064 sq m
Storage system: 1
Underground sump (volume): 100,000 litres
Recharge system: 1
Recharge well: 2.5 m x 2.0 m x 3.0 m
Recharge bore: 165 mm dia, 200 m deep
Cost: Rs 4.73 lakh
Date implemented: 2005

Designed and implemented by *Gujarat Water Supply and Sanitation Board, Junagadh*

Table: Water quality of the tank

Parameters	Permissible limit (mg/l)	Test results (mg/l)
pH	6.5 – 8.5	7.33
Total dissolved solids (TDS)	2,000	500
Total hardness (as $CaCO_3$)	600	160
Total alkalinity (as $CaCO_3$)	600	120
Calcium (as Ca)	200	32
Magnesium (as Mg)	100	19
Chloride (as Cl)	1,000	160
Sulphate as (SO_4)	400	36
Nitrate (as No_3)	45	34.3
Fluoride (as Fl)	1.5	0.4

Notes: mg/l: milligrams per litre, $CaCO_3$: calcium carbonate; tested: January 2012
Source: Unit Manager, Coordination, Monitoring and Support Unit, WASMO, Junagadh

RASHTRAPATI BHAWAN

NEW DELHI

Rashtrapati Bhawan, India's Presidential Estate, captures 100 per cent of rain that falls within it. Rainwater harvesting was initiated in 1998 and today there are 25 structures to capture rainwater and recharge the aquifer. In 2010, Rashtrapati Bhawan received an ISO 14001:2004 certification for its green initiatives.

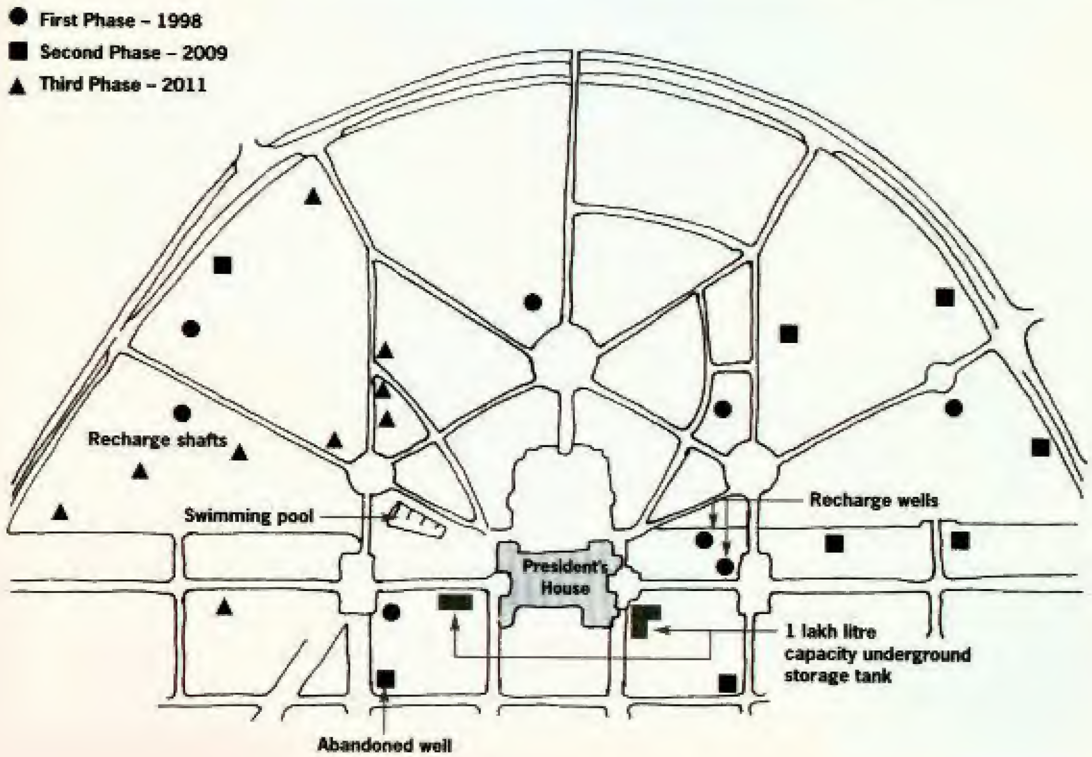
In November 1998, the late K R Narayanan, the then President of India, invited Centre for Science and Environment (CSE) to suggest measures to harvest rainwater at the Rashtrapati Bhavan. An advisory committee was set up by CSE, which developed a water harvesting plan. The scheme was implemented by the Central Public Works Department (CPWD) and Central Ground Water Board (CGWB) in consultation with CSE.

WHY: HIGH DAILY WATER DEMAND

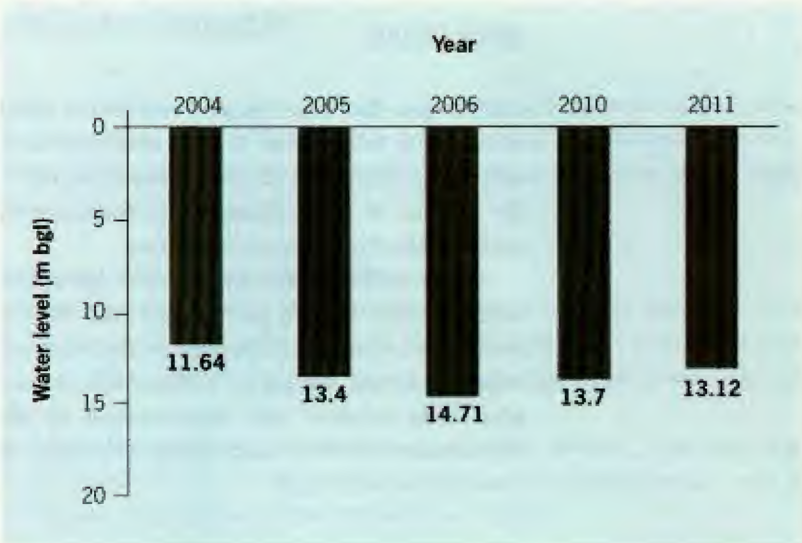
The Presidential Estate covers an area of 360 acres (1,456,868 sq m) and there are about 7,000 people residing on the estate. In addition, the estate receives approximately 500 visitors every day. The daily water requirement for domestic uses and in the numerous gardens is approximately 2,000,000 litres per day. More than one-fourth of this demand was met by borewells, which resulted in an alarming decline in groundwater levels.

ALL RUN-OFF USED FOR RECHARGE

The Central Public Works Department, began to implement rainwater harvesting in 1998, based upon a design prepared by the Centre for Science and Environment. There was a rise in the groundwater in a short span of one year after the installation of the structure. After



Graph: Groundwater decline arrested



Note: m bgl: metres below ground level
Source: Central Public Works Department

seeing the impact of their initial efforts, they worked over the next decade to build more rainwater harvesting structures.

- Phase 1 (1998): Eight recharge structures and one underground sump of 1 lakh litres.
- Phase 2 (2009): Eight recharge structures
- Phase 3 (2011): Nine recharge structures and one underground sump of 1 lakh litres.

The estate also used all the dry dugwells in the premises for recharging. The 900,000-litre capacity swimming pool in the estate is connected to a dry dugwell, so that during the periodic emptying of the pool, water can be used for recharging instead of being drained away.

IMPACT

The President's Estate monitors the water level regularly through a piezometer at different locations. Annual data recorded shows that from 2003 onwards, when the monitoring started, the Estate has managed to arrest groundwater decline. The pre-monsoon reading of groundwater level in June 2003 was 12.06 metres below ground level (m bgl) while the post-monsoon reading in September 2011 was 13.12 m bgl (see Graph: *Groundwater decline arrested*).

In the first year itself, there was a 97 cm net increase in the groundwater level. Seeing this, more rainwater harvesting structures such as an injection well, recharge shaft and recharge trenches with borewells and allied structures were constructed. Another underground storage tank of 1 lakh litre capacity was also built.

System details
Total catchment area: 1,456,868 sq m
Recharge well (open wells): 3
Underground sumps: 2 (100,000 litres each)
Recharge wells: 22

Designed and implemented by
Centre for Science and Environment, Central Ground Water Board, and Central Public Works Department, New Delhi

INDIAN SPINAL INJURY CENTRE

VASANT KUNJ, NEW DELHI

The Indian Spinal Injury Centre (ISIC) is a premier super-speciality hospital for advanced spine, orthopaedic and neuro-muscular problems. It is spread over 12 acres (48,562 sq m) of land in Vasant Kunj and the campus includes the hospital, staff residences, and other service areas. The hospital has managed to avoid buying water and at the same time ensured a sustainable supply of groundwater.

WHY: POTENTIAL FOR RECHARGE IS LIMITED

The hospital is solely dependent on groundwater extracted from 4 borewells. The area is underlain by quartzite rocks and the potential for natural recharge is limited. Therefore, use of groundwater must be limited and judicious.

The hospital faced a rapid decline of groundwater level in 2002, when it went down to 32 metres below ground level (m bgl). It was at this time that the hospital went in for rainwater harvesting.

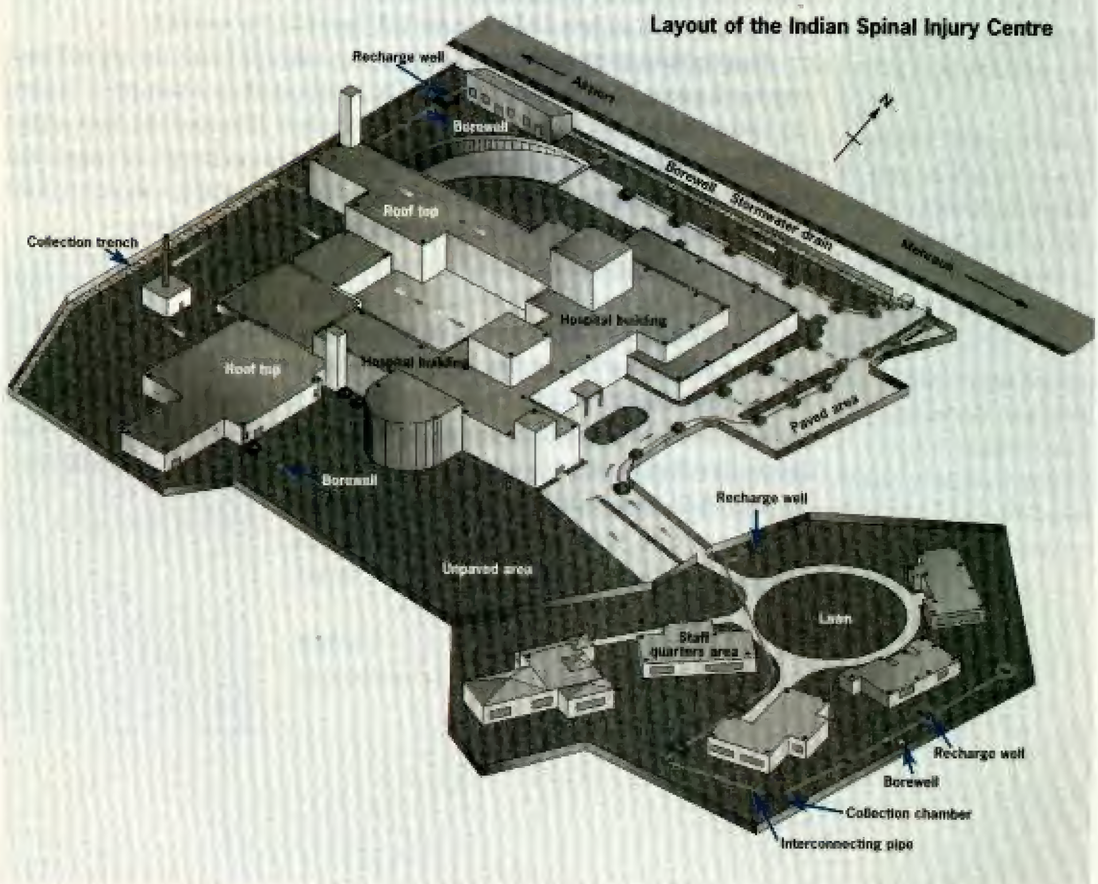
Groundwater levels have been managed well. The hospital does not need to buy water from outside

MULTIPLE COLLECTION MEASURES

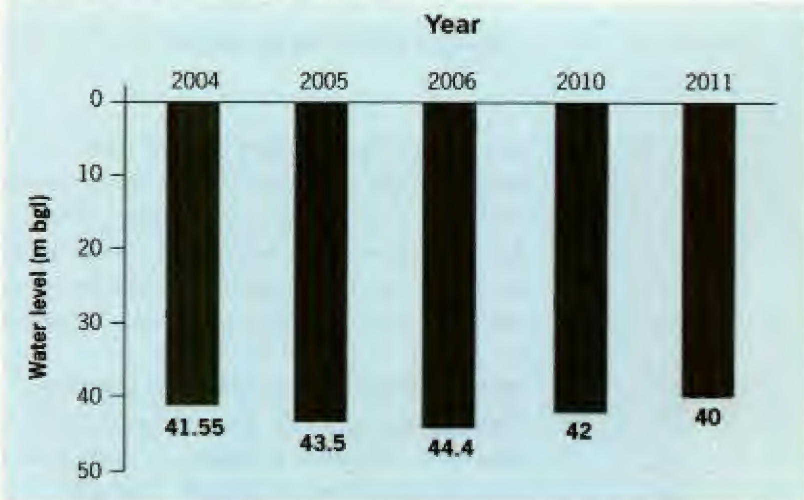
Rainwater harvesting structures have been laid across the campus, both on the hospital building and the staff quarters area.

The rooftop rainwater and the surface run-off from the western part of the hospital building are drained into a stormwater drain that

Layout of the Indian Spinal Injury Centre



Graph: Steady water levels, no shortages



Note: m bgl: metres below ground level
Source: Centre for Science and Environment, New Delhi

runs along the west side of the building. This water is then diverted into a recharge well located at the north-west corner of the campus near an existing borewell. A part of the rooftop rainwater from the east side of the hospital building and run-off from the paved area are diverted through a network of pipes and collection chambers to another stormwater drain that runs to the north of the premises. This run-off is also diverted to the same recharge well located near the borewell.

This recharge well has two compartments, and the run-off undergoes two stages of filtration before it enters the recharge borewell. Layers of brickbats (broken bricks) and sand ensure that the water is cleaned of most debris before it percolates into the aquifer.

The rooftop rainwater and the surface run-off from the paved and unpaved areas of the staff quarters are collected in chambers, which are interlinked by pipes. This water is then diverted to two other recharge wells. A part of this water is diverted to recharge the east side of the staff quarters. The rest is harvested by converting a dry borewell into a recharge well near the entrance of the staff quarters.

System details
Plot area: 12 acres (48,562 sq m)
Recharge wells: 3
Hospital side recharge well: 2.75 m x 2.13 m x 1.82 m
Staff quarter side recharge well: 1.5 m dia, 2 m deep
Recharge bore: 100 mm dia, 20 m deep
Cost: Rs 80,000
Year implemented: 2002

Designed by *Centre for Science and Environment*
Implemented by *The Indian Spinal Injury Centre*

IMPACT

The construction of the rainwater harvesting system was completed in October 2002 and the water level, when measured in February 2003, was found to be 32 m bgl. Thus, even though the number of visitors and patients have increased, the hospital has been able to sustain the water levels (see Table: *Steady water levels, no shortages*). Even during lean periods ISIC does not face any water shortage.

GOVERNMENT HOSPITAL

ANGAMALY, KOCHI, KERALA

ANDHYODAYA

Ferrocement water storage tank

The government hospital at Angamaly is located about 33 km north of Kochi, in the state of Kerala. The town is now the hub of new development. The hospital receives about 250 patients every day and has 20 beds. There are 35 staff members.

System details
Rooftop area: 185 sq m
Volume of storage tank: 90,000 litres
Cost: Rs 2.57 lakh
Year implemented: 2006

Designed by *Andhyodaya, Kerala*
Implemented by *Community Health Centre, Government Hospital, Angamaly*

WHY: THERE IS NO MUNICIPAL SUPPLY

The hospital does not receive any municipal water supply, the only source being groundwater, which is pumped through an open well. The well water is used for drinking purposes. Angamaly in Ernakulam district is one of the blocks categorised as 'critical' in terms of groundwater development by the Central Ground Water Board. That makes it doubly necessary to harvest rainwater.

RAINWATER FOR POTABLE USE

The area of the rooftop is 185 sq m. The water from the flat, cemented roof is directed to the downtake pipe through one outlet. The PVC pipe carries the water to the filter and then to a 90,000 litres ferro-cement tank. The rainwater is used for non-potable purposes.

IMPACT

Groundwater decline has been arrested.

SHRI RANGJI TEMPLE

VRINDAVAN, MATHURA, UTTAR PRADESH

At the Sri Rangji Mandir in Vrindavan in Mathura district of Uttar Pradesh, constructed in 1851, rainwater harvesting has greatly mitigated the problem of waterlogging

In 2007, the temple authorities approached Centre for Science and Environment for assistance in implementing a rainwater harvesting system.

WHY: GROUNDWATER DRYING UP

Over-extraction of groundwater in Vrindavan has resulted in rapid decline of groundwater levels and the water has become extremely saline. The temple complex sources its water from open wells. Water levels in these wells as well as that of the *pushkarni* (temple tank) have been steadily going down. The temple also gets waterlogged in the rainy season as it is at a lower level than the road.

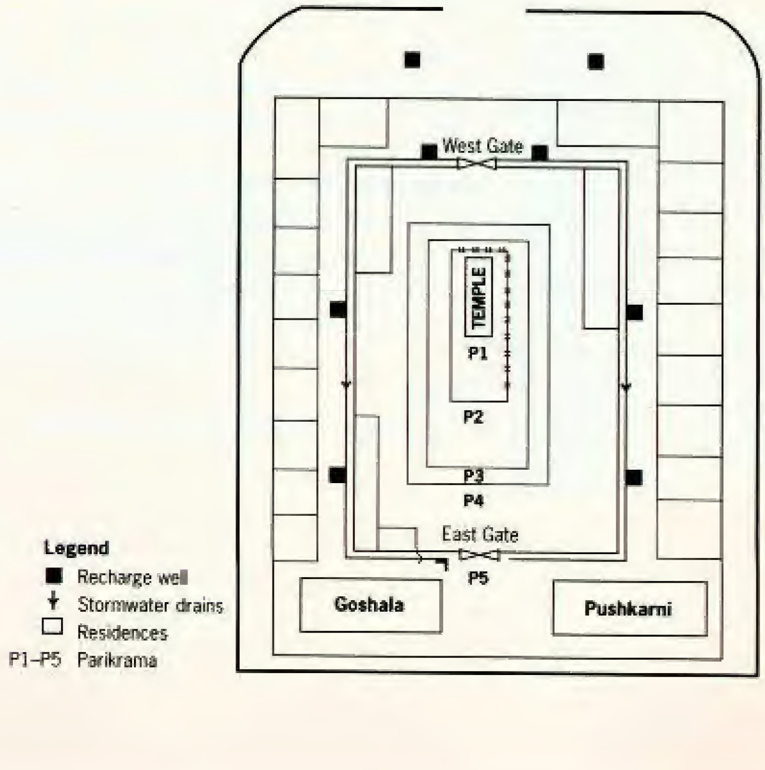
RECHARGE: FROM PAVED SURFACE TO STORMWATER DRAIN

Stormwater drains run around the temple between the fourth and the fifth *parikramas*. A series of recharge wells were constructed along the stormwater drains. In addition, two more recharge wells were constructed at the outermost corridor of the temple at the western end. As the residences of temple staff are situated in this courtyard, water from the roof and paved courtyard is channelled into the stormwater drain, ultimately recharging groundwater.

Harvested rainwater stored in a large tank suffices for the drinking water needs of the staff throughout the year

IMPACT

According to Sri Aditya Raghunath, the temple head priest, there has been appreciable improvement in curbing waterlogging. He adds that there has been improvement in the water level and quality as well. This experience has kindled interest in rainwater harvesting in other temples in the town.



Designed by *Centre for Science and Environment, New Delhi*
Implemented by *Sri Rangji Mandir, Vrindavan*

ST MARY'S CHURCH

KORAMBADAM, KOCHI, KERALA


SALAHUDDIN SAIPHY / CSE

The well-maintained ferrocement storage tank

St Mary's Church serves the community of Korambadam not only when it comes to the soul, but also for more mundane but essential needs such as water. Rainwater harvested from the roof of the church is made available to the people living in nearby areas for potable use through a network of pipes.

The project was implemented by the Rotary Club of Cochin with technical assistance from Andhyodaya, a local non-governmental organisation.

WATER FOR THE LAITY

The rooftop area of St Mary's Church is 550 sq m. Rainwater from the roof of the church is collected through a network of gutters. After the diversion of first flush, rainwater is collected in a ferrocement tank after filtration. The filtration tank has sand and gravel as filter media.

Apart from usage by the Church, water is also used by 150 locals living nearby for drinking and cooking purposes. The groundwater in this area is saline and people use the rainwater as long as it lasts for drinking and cooking.

With 130 rainy days, rainwater harvested is adequate for the water needs of the locals for three months

IMPACT

The Church has made a network of pipes with three community taps to provide access to the village people. As there are nearly 130 rainy days, rainwater is sufficient to meet water requirements of the locals for three months.


SALAHUDDIN SAIPHY / CSE

Water spout for villagers

System details
Roof area: 550 sq m
Capacity of tank: 52,000 litres
Pipes: 300 m
Cost: Rs 1.05 lakh
Year implemented: 2007

Designed and executed by *Andhyodaya, Kochi*
Implemented by *Rotary Club of Cochin Lords*

VEERANARAYANA TEMPLE

GADAG

The ancient Veeranarayana Temple is one of five Vishnu temples in Karnataka. It was built in AD 1117 by Vishnuvardana, a Hoysala king.

The quality and quantity of water in the well has improved after the temple authorities went in for rainwater harvesting on the advice of a pilgrim in 2005.

WHY: WATER LEVELS DECLINED AND BECAME SALINE

Since the 1980s, the water level of the temple began to decline, even as the water started becoming saline. Water was so saline that it became unfit for use and temple authorities began to drill borewells. They drilled four wells in the last decade alone, as each would dry up in a very short while. For all temple activities, *naivedya* and *abhishek*, the temple switched to borewell water. In this area, annual average rainfall is a little more than 600 mm and rainy days are below 50.

SIMPLE PERCOLATION TRENCH

The temple authorities sought the help of government engineers to design a rainwater harvesting system for them. The engineers devised a very simple percolation pit to trap rainwater and allow it to percolate into the ground. The percolation pit is a trench with a volume of 16 cubic metre (cu m). The pit is filled with filter media of sand and jelly up to 3 metres deep. The temple authorities then paved the grounds so that the run-off co-efficiency was increased. Arrangements were made to divert all the water to the pit.

IMPACT

The temple priest, Shri Gopal Krishna Acharya says that water has come back in the open well and its quality has improved to such an extent that it is possible to use it to cook *toor dal*. This, says Gopal Krishna, is the informal test for water quality. Today, the temple uses this open well water for temple rituals, *abhishek*, *naivedya* and when distributing *teerth* to devotees. This same water was once unfit for use. Gopal Krishna says that from being a dry well, water can now be found at a depth of 1.2-1.5 metres below ground level.

A defunct well is live again. The quality of water is also good

SHREE PADRE

Open well of the temple

System details
Plot area: 836 sq m
Dimensions of recharge pit: 12 ft x 8 ft x 6 ft
Year implemented: 2005

Designed by *Horticultural Department, Gadag*
Implemented by *Shree Veeranarayana Temple, Gadag*

SOMARPANN CONVENT

MANGALORE, KERALA

SHREE PADRE

Sister Jeraldine in front of the underground sump

Somarpann Generalate is the administrative headquarters of the Ursuline Franciscan Sisters, a Catholic congregation located in Derlakatte, Mangalore.

Rainwater harvesting was built into the planning of the convent at the construction stage with the aim of using stored rainwater directly as well as for recharging the groundwater. The planning of the entire system, including the filters, was undertaken by Sister Jeraldine of the convent, who has no technical background.

The rainwater harvesting system was conceived by Sister Jeraldine who had no technical expertise. About 8,000 litres of stored rainwater is used for drinking, cooking and other domestic purposes daily

WHY: FAILING BOREWELLS

The Derlakatte area is known for its declining groundwater table, with borewells failing regularly. The area is hilly and overlays hard lateritic rocks. When the building was being constructed, there was difficulty in locating a groundwater source. At this time, Sister Jeraldine D'Souza, the councillor general of the organisation, suggested that they incorporate a rooftop rainwater harvesting system in the design of the building and tap the abundant rainfall of the coastal region.

THREE-STAGE FILTRATION SYSTEM

Sister Jeraldine, who had spent many years in north-east India, had witnessed first-hand how rainwater was used for various purposes in Mizoram. With the ample roof area of 650.32 sq m, and rains occurring at least six months a year, such a system was a natural step


SR. JERALDINE

Filter tanks that provide cleaned water to the sump

to take. It was decided that during the monsoon months, water for all uses would be sourced from the rainwater harvesting system, thereby saving groundwater.

An underground RCC tank of 75,000 litres was built to store water, brought down from the roof through several downtake pipes at the rear of the building. A filter system consisting of a desiltation tank and two chambers, filled with sand and charcoal, was also constructed. The filtered water passes to the underground sump from where it is pumped to an overhead tank, 25,000 litre in capacity.

The overflow from the tank is used to recharge the groundwater by using the area around a borewell as a recharge pit. This is filled with filtration media made of sand, chips and boulders.

System details
Total rooftop area: 650.32 sq m
Volume of the tank: 75,000 litres
Filtration tanks: 3 tanks (1 m x 1 m x 1.2 m, each)
Cost: Incorporated as part of construction
Year implemented: 2006

Designed and implemented by *Sister Jeraldine, Samarpann Convent*

IMPACT

At any given time, there are at least 20-25 persons living in the convent. Stored rainwater is used for drinking, cooking and other domestic purposes (about 8,000 litres per day). This way, a total of 14 lakh litres of groundwater is conserved every year. The garden is not watered during the monsoon months. In the dry period, the garden needs a lot of water and this water is pumped out of the borewell or an open well, recently constructed.

MALANKARA SOCIAL SERVICE SOCIETY
THIRUVANANTHAPURAM, KERALA

12

INSTITUTIONAL

SALAHUDDIN SAIFHY / CSE

Ferrocement tank of 1.5 lakh litre capacity

Rainwater meets more than half of the total water demand at the administrative office of Malankara Social Service Society (MSSS) located in the municipal limits of Thiruvananthapuram. The MSSS building is also connected to the city supply.

The MSSS is a non-profit organisation that undertakes a wide range of activities aimed at supporting and improving quality of life of the rural poor. It is the social work organ of the Major Archdiocese of Thiruvananthapuram. The Society promotes the implementation of rainwater harvesting in Kerala under the Jalanidhi programme.

Rainwater meets much of the water demand. It is used for non-potable purposes. Municipal water is used for drinking

WHY: SHORTAGE OF MUNICIPAL WATER

In 2004, the institution faced acute water shortage as the municipal supply was insufficient and unreliable. Therefore, in the same year, MSSS constructed a system to harvest rainwater at its own building in 2004.

System details
Roof area: 139.35 sq m
Number of tanks:
1 (ferro-cement)
Capacity of tank:
150,000 litres
Filter tank: 2,000 litres
Filter materials: sand, charcoal, metal
Cost of system in 2004:
Rs 1.5 lakh

Designed and implemented by
Malankara Social Service Society

SEPARATE STORAGE

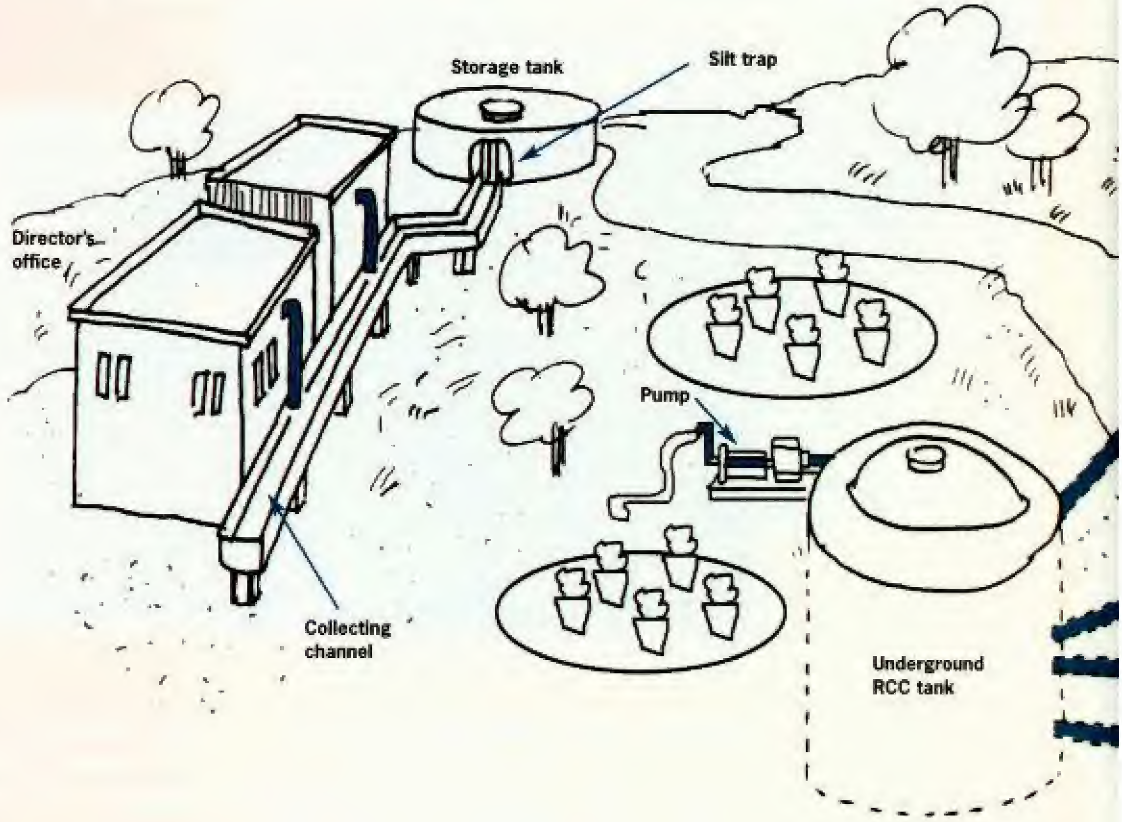
The roof area of the building is 1,500 sq m and the collected water is diverted to a ferro-cement tank of 1.5 lakh litre capacity. The water passes through a filter tank with sand-gravel and charcoal. The filter tank is cleaned twice a year. There are separate tanks to store municipal water and rainwater.

IMPACT

The MSSS officials say that the rainwater harvesting system meets between 50-55 per cent of their total water demand.

The building has 30 regular staff members. In addition, there are usually about 40-50 temporary visitors who come to attend various programmes conducted by the Society. The water stored in this rainwater tank lasts them for almost four months.

The rainwater is used for all non-potable purposes. It supplements the municipal supply, which is used for drinking purposes.



CENTRAL ARID ZONE RESEARCH INSTITUTE

JODHPUR, RAJASTHAN

The Central Arid Zone Research Institute (CAZRI) undertakes basic and applied research towards development of sustainable farming systems in arid ecosystems. It has an experimental farm where medicinal herbs are grown.

WHY: PLANTS REQUIRE CLEAN WATER

The plants require great care and water of high order of purity. Rainwater is harvested to irrigate these plants.

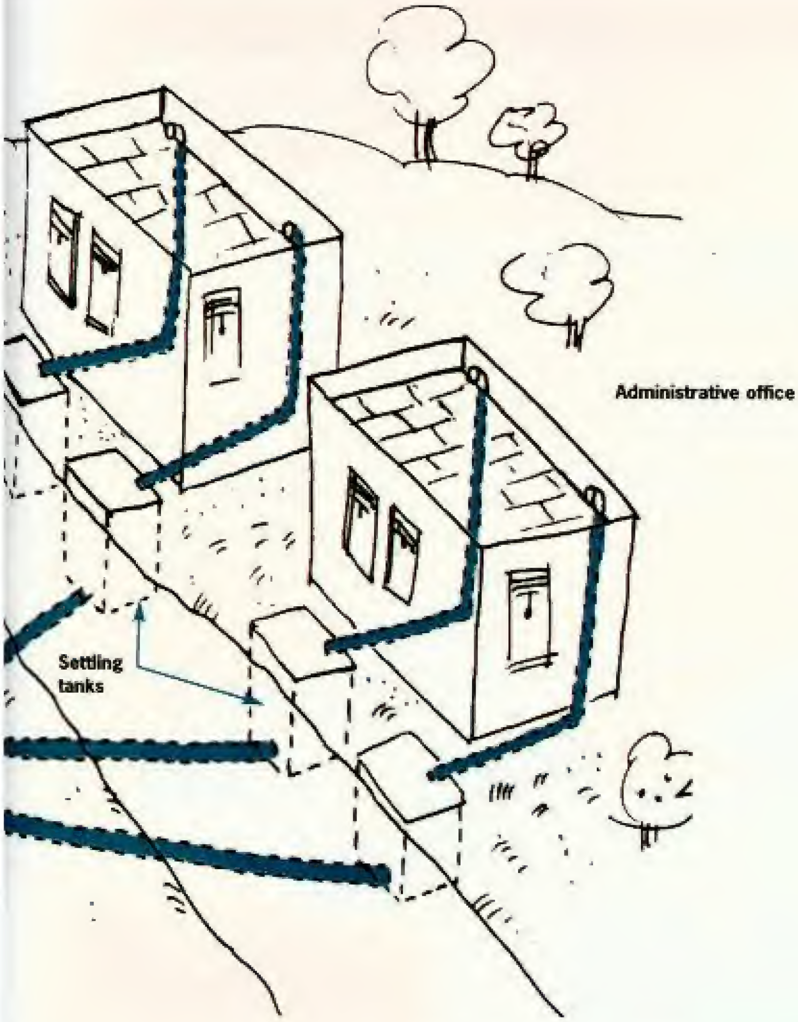
CHANNELS OF RAINWATER

The main office of CAZRI harvests the rainwater that falls on the rooftop of the administrative block and the director's office. The water is stored in two tanks and used for irrigating 4 acres (16,187 sq m) of land where medicinal plants are grown.

Water that falls on the roof of the *administrative block* is diverted through four outlets and directed to downtake pipes. The water is led through underground pipes to four settling tanks, from where it flows into the main RCC tank. A solar operated pump of 3 HP is used to irrigate the plants.

Rainwater irrigates sensitive medicinal plants at this research station

Water from the first floor roof of the *director's office* is also harnessed and is brought down through seven outlets which flow into a RCC channel constructed below, which is 217 m long and connects to



the tank. The channel is stone-lined and plastered with cement. There is a silt trap at the mouth of the tank so that clean water can enter the tank. Rainwater collected from the three outlets of the ground floor is also collected in the same channel.

Table: System details

Parameter	Director's office	Administrative block
Total roof-top area	1,500 sq m	1,700 sq m
Volume of storage tank	300,000 litres	300,000 litres
Settling tank		0.5 m x 0.6 m x 0.3 m
Cost	Rs 1.88 lakh	Rs 4.5 lakh
Year implemented	1992-93	2005

Source: Centre for Science and Environment, New Delhi

Designed and implemented by *The Central Arid Zone Research Institute, Jodhpur*

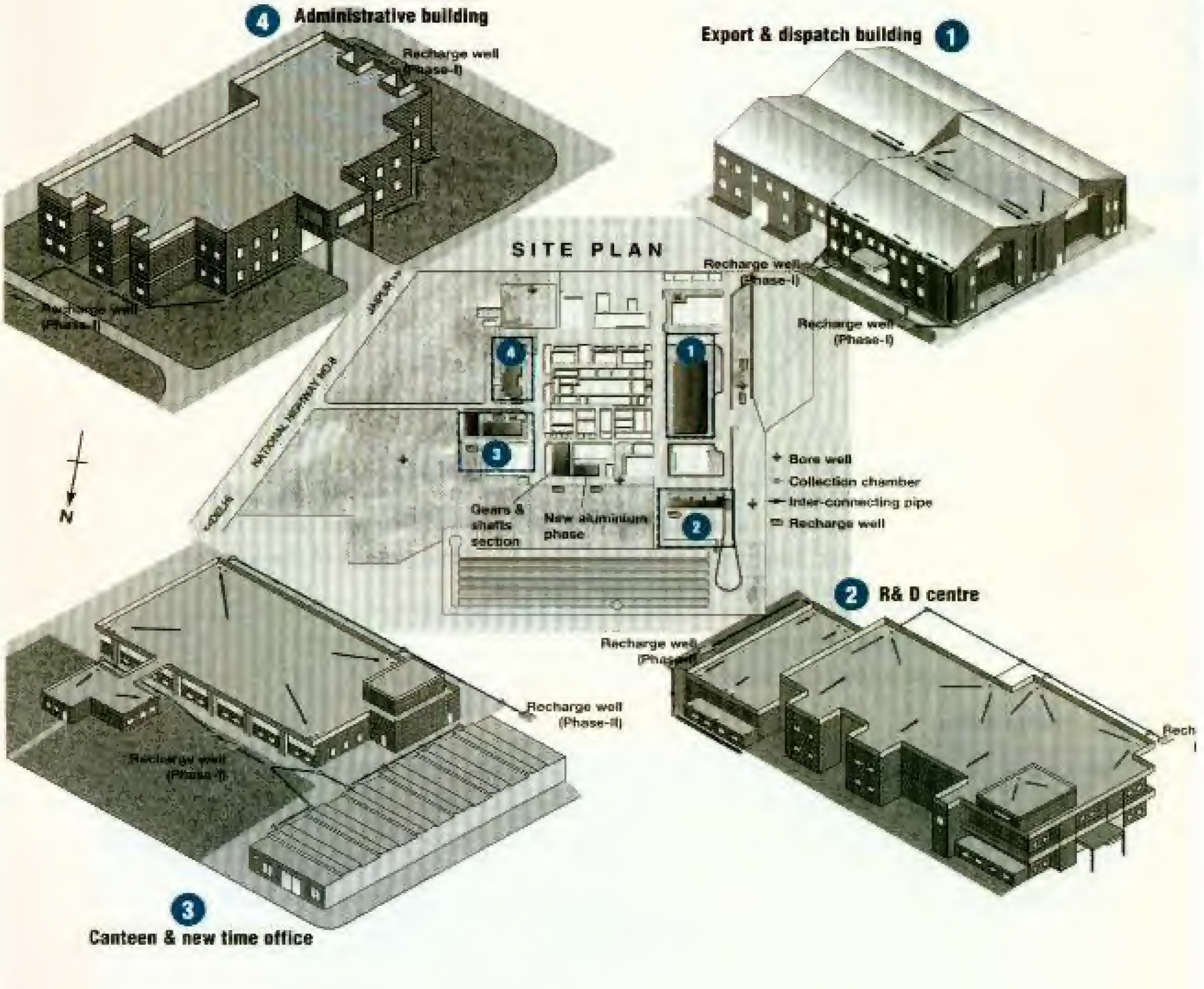
13

Industrial and commercial

Industry

HERO MOTOCORP

DHARUHERA, REWARI, HARYANA



Systematic rainwater harvesting has maintained the groundwater level The level has risen by 3 m

Hero MotoCorp, Dharuhera in the state of Haryana has made a major effort to harness, in stages, more and more of the rooftops of its buildings for rainwater harvesting. At the same time, it has taken measures to reduce its water usage. The factory uses only groundwater – for the manufacturing process, canteen, gardening and personal uses by staff as well as for the bachelor's hostel. It accesses groundwater through six tubewells.

Table: Rainwater harvesting, block by block

Phase	Buildings	Recharge wells	Date of completion	Cost (Rs lakh)
I	Administrative building New time office Environment, health and safety building Canteen (part) R&D centre (part), dispatch & export	6	June 2002	6
II	Gears & shaft section, new aluminium phase Canteen (remaining part) R&D centre (remaining part) and tool room, old building	4	February 2004	6
III	Gurukul (A block) Bachelors hostel (B, C, D & E blocks)	4	March 2007	6
IV	New expansion plant, road run-off from administrative block, road and exit gate (3) road	8 injection wells	February 2009	35

Source: Hero Motocorp, Dharuhera

WATER FROM ROOF AND ROAD RUN-OFF

Beginning in 2002, when it constructed six recharge wells, the workshop today has 22 recharge wells capturing water from the rooftops of most of its buildings (excluding old buildings of the frame and engine plant and factory sheds). It has also begun to harvest road run-off. The work has been done in four phases (see Table: *Rainwater harvesting, block by block*).

The factory diverts roof run-off through downtake pipes to collection chambers for settlement of silt and sediment. Thereafter, water is taken to recharge wells filled with filter media so that filtered water enters the recharge pipes.

Water harvested from roads that lead to the 'No 3' exit gate and the administrative building is diverted through open drains to de-silting chamber and to injection wells filled with filter media. For road run-off recharge wells filter media also includes an activated charcoal layer.

Rainwater harvesting undertaken up to phase III cost Rs 18 lakh, while phase IV was worth Rs 35 lakh. The total cost was Rs 54 lakh. The factory has made plans for Phase V.

IMPACT

The steady recharging of the aquifer using clean rainwater from rooftops has ensured that groundwater level has not only been maintained but has actually risen by 3 m – from 20 m in November 2004 to 18.1 m in December 2011.

System details
Plot area: 58 acres (234,717 sq m)
Rooftop area covered under RWH: 23,977 sq m
Road area covered: 5,725 sq m
Dimensions of recharge wells: 3 m x 2 m x 3 m
Dimensions of recharge bores: 203 mm dia, 40 m deep
Cost: Rs 54 lakh
Year implemented: 2002-09

Designed by *Centre for Science and Environment, New Delhi (Phases I-III)*
Implemented by *Safety & Environment Division of Hero MotoCorp, Dharuhera*

JOHN FOWLER (INDIA) PVT LTD

BOMMASANDRA, BENGALURU

John Fowler (India) Pvt Ltd is located in the Bommasandra Industrial Area, Bengaluru and was set up in 1966 to manufacture filters and filtration systems for industrial applications. A rainwater harvesting system was designed and implemented by the Bengaluru-based Technology Informatics Design Endeavour (TIDE).

WHY: DECLINING WATER LEVELS IN BOREWELLS

The factory employs about 100 persons and has about 250 working days in a year. It is situated on a plot 6 acres (24,281 sq m) in area. The factory has a total daily demand of approximately 7,300 litres, of which roughly half is used for gardening, a major part of its total water needs. The company used to source all its water from five bore/tubewells. Over the years, the yield of the borewells declined to less than 180 litres per hour (LPH). The factory started purchasing water for all its needs – from drinking to gardening.

HARVESTING FOR STORAGE AND RECHARGE

TIDE recommended water harvesting for both storage and recharge. Rainwater is collected from three buildings – the workshop, canteen and administrative building.

Rainwater from half the rooftop (1,500 sq m) of the workshop building is collected through gutters and diverted to three 'Sintex' tanks, each of 5,000 litres capacity. During the rainy season these tanks fill at least 50 times.

Water from the remaining half of the roof of the workshop is led into the stormwater drain, filtered and led to a sump of capacity 25,000 litres. This stored rainwater is used for washing, flushing as well as gardening.

Besides the roof, water from paved and unpaved areas is recharged to the aquifer through 80 recharge (percolation) pits constructed within the stormwater drains, four recharge wells and a recharge trench. There is a two-way flow between the storage and recharge structures. Excess water from the stormwater drain is led into the filter unit and the filtered water is taken to the sump. Overflow from the sump is diverted to recharge wells.

Rainwater harvesting has ensured that groundwater levels are maintained, and the yield has also increased

SALAHUDDIN SAIPHY / CSE

Underground storage

SALAHUDDIN SAIPHY / CSE

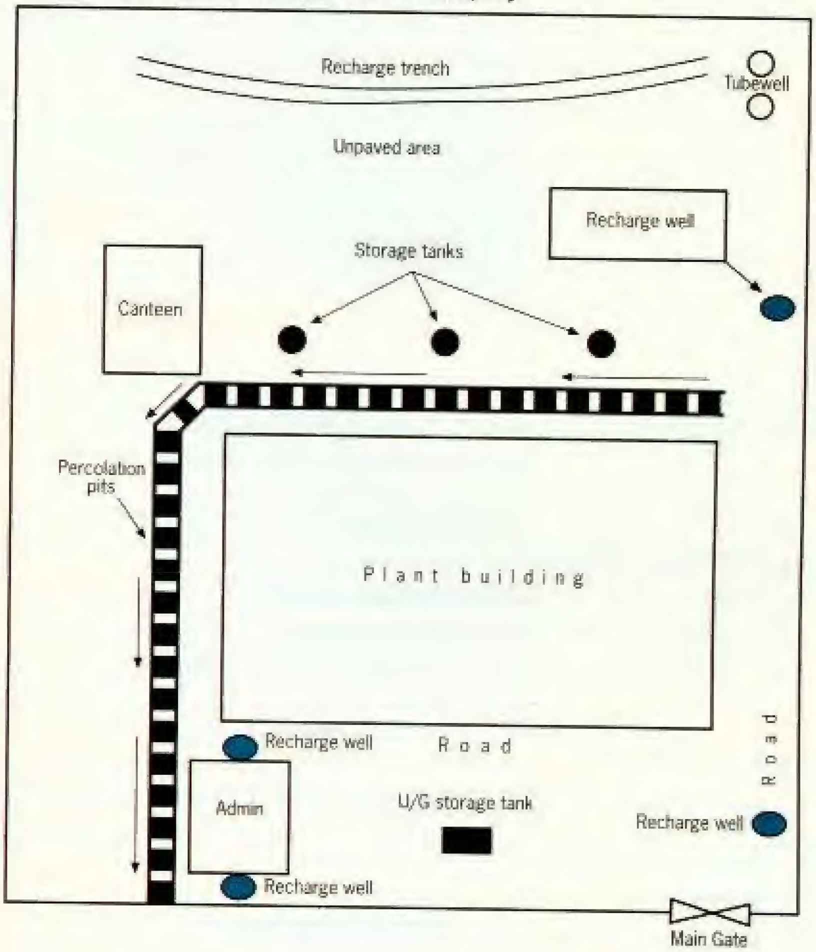
Overground storage

Table: Groundwater count (2007-2011)

Location of borewell	Groundwater level (m bgl)		
	December 2004	October 2007	August 2011
Near security gate	20.15	17.48	17.53
Behind main building	22.75	19.77	19.14
Near old OHT	22.80	21.30	20.09
Near admin (east side)	20.45	16.90	17.50
Near admin (west side)	–	17.60	16.85

Note: m bgl: metres below ground level
Source: Technology Informatics Design Endeavour, Bengaluru

Figure: The water harvesting plan of the company



System details
Plot area: 24,281 sq m
Roof area of workshop: 3,000 sq m
Storage system: 3 Sintex tanks (5,000 litres each, 1 sump of 25,000 litres)
No of recharge pits: 80
Dimensions of pits (in stormwater drain): 1 m x 0.5 m x 1 m
No of recharge wells: 4
Depth of recharge wells: 42-124 m
Daily demand: 7,300 litres
Cost: Rs 12 lakh
Year implemented: 2004

Designed by *Technology Informatics Design Endeavour (TIDE), Bengaluru*
Implemented by *John Fowler (India) Pvt Ltd*

IMPACT

Rainwater harvesting has enabled the factory to maintain groundwater levels, the primary source of water. Water quality and water levels are monitored regularly by TIDE (see Table: *Groundwater count*). According to them, one defunct borewell has started yielding water at the rate of 3,000 litres per hour (LPH) and another working borewell continues to yield water. There was an improvement in the yield of this borewell, from about 180-3,000 LPH.

Shopping complex

GARIAHAT MALL

KOLKATA, WEST BENGAL


SALAHUDDIN SAIPHY / CSE

The Gariahat Mall

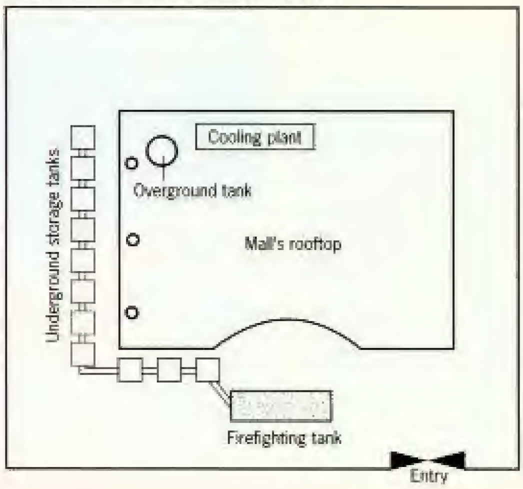
At the Gariahat mall, located in south Kolkata, rainwater collected from the rooftop areas is used to run the water cooling plant and meets the requirement of the centralised air conditioning system throughout the year. The mall is spread over an area of 9,300 sq m, with a roof area of 6,200 sq m.

HUGE STORAGE CAPACITY

The rooftop rainwater from the mall building is gathered in collection chambers and passed through filtering media made up of pebbles, gravels and charcoal. After filtration, the water is directed to 11 storage tanks, constructed underground in a series along the walls of the mall. The total capacity of the tanks is 100,000 litres. This water is pumped to the top of the mall for the water cooling systems. Water for all other uses is sourced from the municipal supply.

Rainwater is used in the water cooling plant of the centralised air conditioning system

Figure: Rainwater harvesting plan



System details
Rooftop area of the mall: 6,200 sq m
Storage systems: 11 tanks (100,000 litres capacity)
Project cost: Rs 5 lakh
Year implemented: 2006

Designed by *Ranjit Gupta, Interdesign, Kolkata*
Implemented by *Gariahat Mall, Kolkata*

Hotels

HOTEL CEDAR INN

DARJEELING, WEST BENGAL

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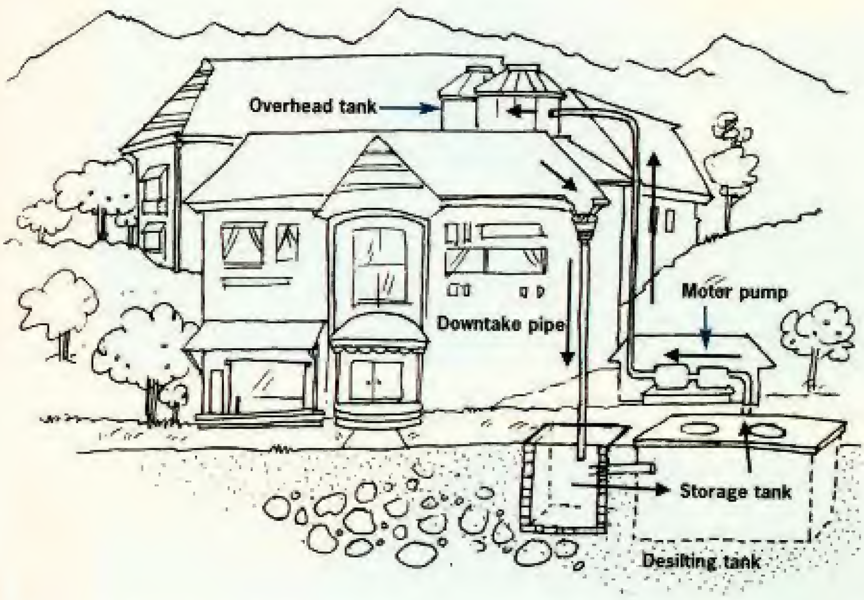
INDUSTRIAL AND COMMERCIAL



At the Hotel Cedar Inn located on the upper reaches of Darjeeling, a popular hill station in eastern India, stored rainwater is used in all guest rooms for all non-potable uses. The rainwater harvesting system was fitted when the hotel was built in 1999.

WHY: POTABLE WATER AT RS 7 LAKH ANNUALLY

Rainwater is a critical component of the water supply since the hotel does not get municipal supply regularly. There is no groundwater supply, either. The hotel buys 4,000 litres every day for drinking and cooking at Rs 2,000 per day. This amounts to more than Rs 7 lakh spent on water, yearly, for drinking and cooking. Without rainwater, the hotel would also have to buy water for its non-potable purposes.

Stored rainwater is used throughout the year, especially for flushing toilets

WITH GOOD RAINS, TANKS CAN BE FILLED TO CAPACITY

Rainwater is collected on the rooftop of the main building which is about 12,995 sq m and passes through gutters down to a sedimentation tank. This water is first stored temporarily in a collection tank. Thereafter the water is passed through a Thermax Culligan filter (that filters out the suspended matter in rainwater) and stored in 4 high-capacity storage tanks, both underground (in the basement) as well as overground. The total storage capacity is about 202,000 litres. When it rains well, it takes just about three hours to fill the tanks to capacity.

There are 99 days of rainfall in the hills with the maximum between May and September. There is an appreciable amount of rainfall in other months of the year as well. Stored rainwater is available for use from July through December provided there is another spell of rain in October-November.

System details
Total rooftop area: 12,995 sq m
Storage system: 4 tanks (100,000, 80,000, 30,000 and 10,000 litres capacity tanks) (total capacity: 202,000 litres)
Year implemented: 1999

Designed by
Shasheesh Prasad, architect, Darjeeling
Implemented by
Hotel Cedar Inn

IMPACT

Stored rainwater is pumped to overhead tanks and distributed to the hotel rooms for bathing and flushing. Rainwater is used throughout the year, especially for flushing.

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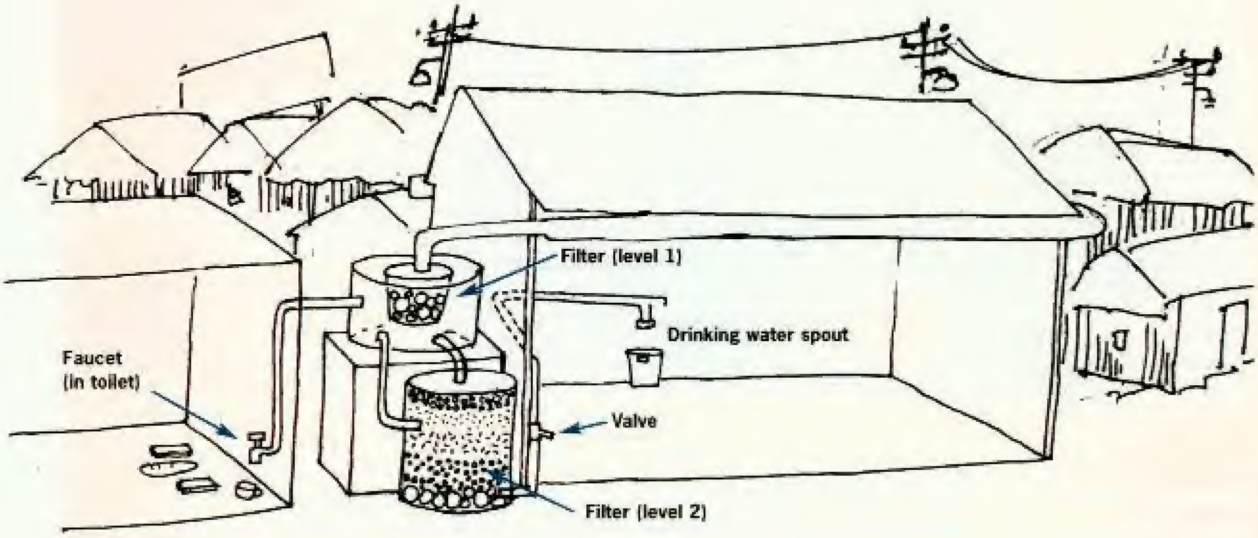
Other urban spaces



KARGIL AND SUKA BIHAR SLUMS

BHUBANESWAR, ODISHA

The Kargil slum in Bhubaneswar is located behind the Lingaraj railway station and is home to fisherfolk and hawkers. Suka Bihar slum is located in Dumduma area of the city. There is no municipal supply here.

Many people would find it difficult to believe that water can be harvested in such urban spaces. Yet, this case study proves they can.

WHY: LACK OF WATER

The Ruchika Social Service Organisation (RSSO) runs *balwadis* (crèches) in both settlements which used to be closed down in summer because of water scarcity. In 2007 the RSSO built simple rainwater harvesting systems in these places.

DRINKING WATER

Rainwater harvesting has ensured that the two *balwadis* stay open in summer. The children drink this water

The total rooftop area of the Kargil slum *balwadi* is 37 sq m and that of Suka Bihar is 29 sq m. The system is identical in both. Rainwater from the sloping galvanised iron (GI) roof is collected in the gutter and directed to a storage tank. At the collection point there is an iron bucket to strain away large impurities. From the storage tank two pipes lead to the toilets and a filtration tank respectively. The filtered water is drunk by the children.

In the dry season, water to the toilets is completely closed off. All available water is used for drinking. The toilets get water from a

SUSHMITA SENGUPTA / CSE

Drinking water tap inside the balwadi

SUSHMITA SENGUPTA / CSE

Iron bucket filter that strains away large impurities

nearby pond.

The system is maintained by the teachers. The iron bucket is cleaned every month, and the filter tank every year.

Designed and implemented by *Ruchika Social Service Organisation, Bhubaneswar*

IMPACT

The NGO has tested quality of the water and found it to be within permissible limits.

System details

Parameter	Kargil *balwadi*	Suka Bihar *balwadi*
Total rooftop area	37 sq m	29.3 sq m
Volume of storage tank	3,000 litres	1,300 litres x 2 tanks = 2,600 litres
Cost	Rs 17,500	Rs 12,000
Year implemented	2007	2005

Source: Ruchika Social Service Organisation, Bhubaneswar

Sports complex

PRABODHAN KRIDA BHAWAN

MUMBAI, MAHARASHTRA

Prabodhan Krida Bhavan (PKB) was set up by the Prabodhan Goregaon Trust, Mumbai in 1991 for the promotion of sports activities. The Trust is a non-profit organisation that works for public welfare with a focus on health services.

The facilities offered by PKB range from a yoga centre, gymnasium, jogger's park and swimming pool to arrangements for athletics, gymnastics, table tennis and karate. It also houses a steam bath, sauna, *jacuzzi* and a restaurant. The Bhawan is located in Siddharth Nagar in the Goregaon (W) area.

WHY: LARGE WATER NEED

Spread over an area of 11,620 sq m, PKB receives over 1,000 visitors daily. The complex sources its water from the municipal supply and also through borewells. Since it needs large quantities of water, a rainwater harvesting system was set up in 2006, with funds from the local legislator (MLA funds).

SURFACE RUN-OFF IS CAPTURED

The rainwater harvesting system has been set up in the stadium complex. Surface run-off is directed to a drain which runs parallel to the periphery of the playground. This water is tapped at three locations and diverted to three recharge wells constructed near the flag post on the eastern side, the ozone swimming pool and the western corner fencing. These recharge wells are provided with three layers of pebbles of varying size to filter out tree leaves and coarse sand particles. In addition, there are two recharge pits to take care of extra run-off from the ground.

The rainwater harvesting system was set up with financial assistance form the local legislator's 'MLA funds'

IMPACT

According to the PKB authorities, groundwater levels and yields have increased. For the swimming pool, PKB used to source water from the municipal supply. Now, it is filled with groundwater, sourced through two borewells. This has resulted in a saving of Rs 5 lakh annually.

System details
Total area: 11,620 sq m
Recharge wells: 3
Dimensions:
2 m X 2 m X 2.3 m
Details of the recharge bore: 200 mm dia and 40 m deep
Cost: Rs 5 lakh
Date of completion: 2006

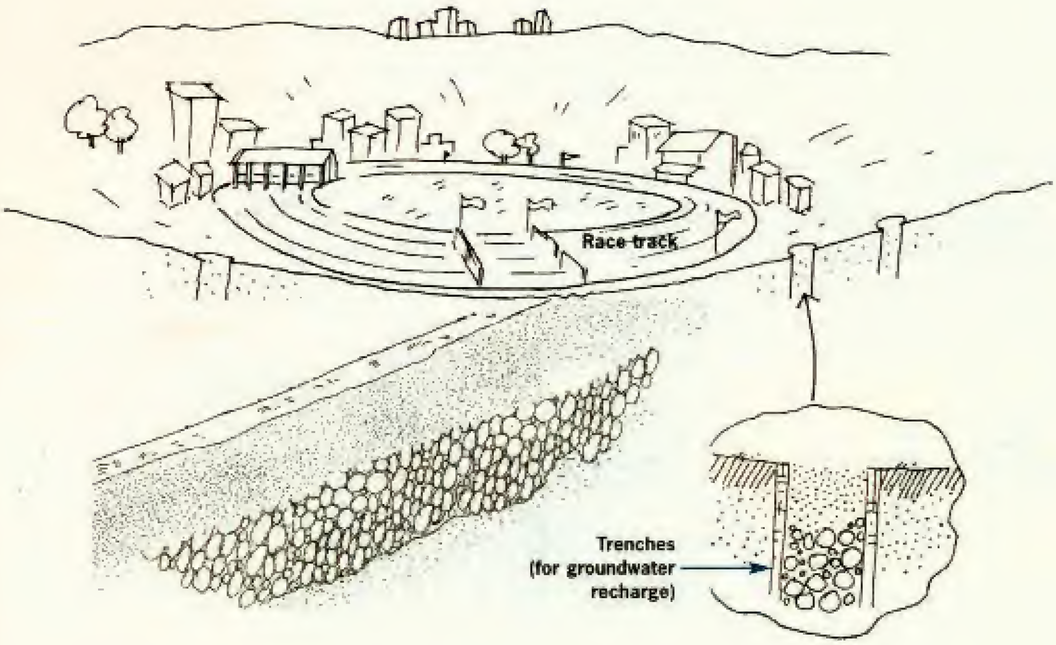
Designed by *Water Field Technologies, Mumbai*
Implemented by *Prabodhan Krida Bhavan, Goregaon*
Funded by *Subash Desai, MLA*

SALAHUDDIN SAIPHY / CSE

With 1,000 visitors a day, the stadium's water needs are large

RACE COURSE

RAJKOT, GUJARAT



The Race Course area of Rajkot, at the heart of the city, is a favourite recreational haunt for the old and young alike. It has well-maintained gardens, walkers' trails and seating spaces along the inner boundary of the race course. The area houses stadiums and sports grounds that regularly host cricket, hockey and football matches. The area is also the hub of commercial activity and some of the premier residential spaces of the city are located in this area.

A rainwater harvesting system was set up here in 2006 at the initiative of the municipal commissioner. This was done in response to the concerns of citizens regarding waterlogging, which was brought to the notice of the Rajkot Municipal Corporation (RMC).

Reduced waterlogging and recharged groundwater – these have been the benefits of RWH

WHY: LOW-LYING WATERLOGGED AREA

The area used to be severely waterlogged every monsoon even as groundwater levels kept falling. The area is low-lying and located at the heart of the city. During the rainy season, run-off from the surrounding elevated areas collects in this space. In fact, the twin problem led to falling land prices. Since some of the most important offices and commercial areas are located in this area commercial activities were affected during the rainy season.

System details
Total volume of 10 trenches: 10,000 litres
Cost: Rs 2 lakh in the year 2001

Designed and implemented by *Rajkot Municipal Corporation*

TRENCHES CONVEY RAINWATER DOWNWARDS

The RMC built 10 trenches around the periphery of the race course, which were filled with filter media. The trenches can convey rainwater quickly downwards, into the ground, even during peak rainfall.

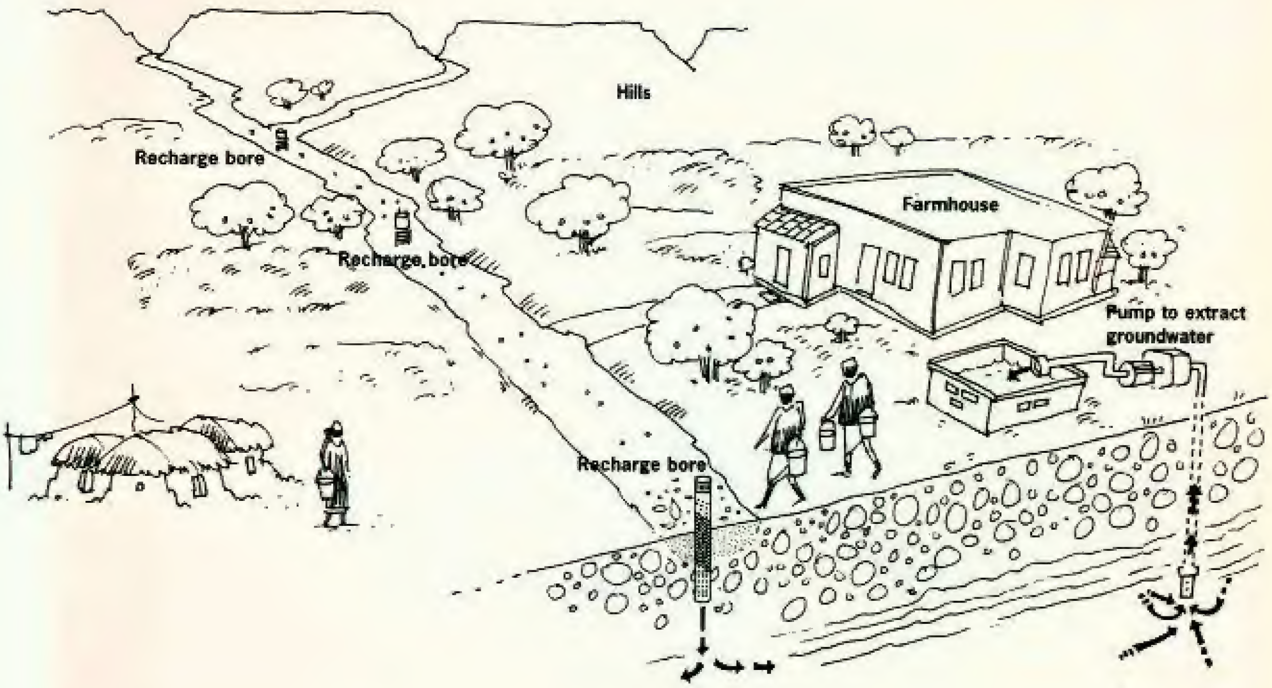
IMPACT

Not only has the problem of waterlogging been solved, but groundwater levels have also risen. The tubewells and borewells in the offices never run dry even during peak summers.

Peri-urban area

FARMHOUSE OF V N SHROFF

INDORE, MADHYA PRADESH



V N Shroff's farmhouse is located in Badiya Kima, a peri-urban area about 8 km from Indore town. The rainwater harvesting system was set up in 2006.

WHY: STEADY DECLINE IN GROUNDWATER

To source water, a tubewell had been installed in the farm in 1995, but discharge from the well declined steadily. As a result, *rabi* crop production dropped to 25-30 per cent below normal.

System details
Distance from tubewell of 3 recharge bores: 15 m, 20 m, 35 m
Depth of 3 recharge bores: 35 m, 57 m, 20 m
Diameter of recharge bore: 15 cm
Length of casing pipe: 7 m
Dimensions of gabion structures: 1.5 m (length) x 1.0 m (depth)
Dimensions of pond: 3 m x 3 m x 2 m

Designed and implemented by
V N Shroff

OPTIMUM RECHARGE

In order to tap rainwater flowing through the stormwater drains, Shroff had three recharge bores constructed between the tubewell and stormwater drain. The casing pipe of the recharge shafts has longitudinal slits and round holes (10 mm in diameter). The upper open portion of the pipe is wrapped with coir rope and surrounded by pebbles for protection and filtration. On the cap of the recharge bores, there are two air vents, each having a 8 mm pipe.

Gabion structures have also been constructed along the stormwater drains. These structures hold water, filtering it in the process. As the water flows through the stormwater channels over the stepped gabion, it percolates vertically into the ground, as well as through the recharge bores bypassing the weathered strata (of hard basaltic rock) to reach the aquifer. Water is retained in the gabion structures along the stormwater drain and percolates slowly into the ground through the filters in the recharge shafts.

Soon after the construction, the first pre-monsoon shower of 50 mm in May 2006 revived the water flow in the tubewell. In order to ascertain whether the system was effective, Shroff added potassium

permanganate in each of the recharge bores. Light pink coloured water flowing through the tubewell confirmed that water was percolating through the recharge shafts into the tubewell.

Shroff also checked the quality of the water by monitoring the TDS levels. The dissolved salts showed an acceptable level of 350 parts per million (ppm). According to Indian standards, average tap water TDS count is expected be 500 ppm.

IMPACT

By 2007-08 the water level had risen to such an extent that there was enough water in the tubewell throughout the year. As a result of rainwater harvesting, the yield of wheat from his farm has increased from 10 to 30-35 quintals/hectare even though he has taken up organic farming. In the *kharif* season he irrigates vegetables, cotton and soyabean crops. He also provides potable water to 20 farm families living near by.

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Urban water bodies

Revival of lakes

KAJIPUKUR AND BAGHAJATIN LAKE

KOLKATA, WEST BENGAL

SUSHMITA SENGUPTA / CSE

Kajipukur lake, cleaned and restored

Citizens have come together to protect, regenerate and maintain urban water bodies. It covers the entire gamut of action – physical cleaning, anti-pollution measures, catchment protections, legal pressure and institutional systems to maintain and sustain the lakes

The Baghajatin and Kajipukur lakes in the Baghajatin area of south Kolkata have been revived through the efforts of local community groups. The Baghajatin Lake Unnayan-O-Tran Samiti, formed in 1989 and Kajipukur Unnayan Samiti, formed in 2002 were instrumental in bringing the locals together and reviving the lake. In fact, today, both organisations have over 600 members each, the former having started with only ten members. Funds were collected from the members and other citizens and with voluntary labour the lakes were desilted and cleaned.

The Baghajatin lake, which is about 19,000 sq m in area, serves nearly 250 people living in Sri Colony, Vidyasagar Colony and S, A and I blocks of Baghajatin area. The lake is located between A and I blocks. Kajipukur lake serves A-block of Baghajatin.

WHY: ENCROACHED DUMPS

There was a time when the Baghajatin area had numerous ponds used by people for fishing and domestic purposes. Over the years the ponds were encroached upon and used as dumping grounds. Kajipukur started deteriorating in the 1970s when it had turned into a waste


Members of Baghajatin Lake Unnayan-O-Tran Samiti

dumping ground. The land mafia had also tried to fill in the pond and convert it for real-estate development.

CITIZENS PITCH IN TO CLEAN THEIR LAKE

The Baghajatin Lake Unnayan-O-Tran Samiti initiated work on the revival of the lake with cash and labour contributions. The pond was cleared of all solid waste and restored. The municipality helped direct wastewater into newly constructed sewer lines. Protective embankments were constructed, and trees were planted around the pond to provide a buffer zone. Separate enclosures for washing clothes were built to prevent contamination of the pond with soap water.

The pond is maintained with care and regularly repaired with the active cooperation of members who also keep a regular watch to ensure that lake water is not contaminated. Lime is added to the pond water three to four times a year to disinfect the water. This keeps the water free of any contamination and the fish healthy. Residents are updated and sensitised to the importance of the pond through regular meetings and seminars. The committee has recently demarcated the catchment of the pond so that proper restoration can be planned.

A similar exercise was carried to clean up the Kajipukur lake. The pond was desilted of accumulated solid waste and its base strengthened. The KUS however, decided against building a concrete *bund* or embankment and, instead, developed a natural *bund* of grass and 150 trees, planted around the pond. Separate enclosures for bathing and washing were built. The municipality helped KUS to build sewer drains to divert wastewater away from the pond and also to build roads around the pond. The KUS also undertook a door-to-door campaign asking people not to throw garbage into the pond.

IMPACT

Today, about 200-300 persons of this area use this pond for bathing, washing and for other domestic purposes.

Implemented by
Baghajatin Lake Unnayan-O-Tran Samiti and Kajipukur Unnayan Samiti

Technical and institutional support by *Vasundhara*

ARKEESWARAR-SURIAMMAN TEMPLE TANK

PAMMAL, TAMIL NADU

January 2012: Catchment area treated for long term recharge with all trees fully grown

The temple tank of Suriamman Koil and Arkeeswarar temples in Pammal, some 30 kms from Chennai, is at least 600 years old and considered sacred. Till the 1970s it was the main drinking water source for the town. Historically, it had a catchment area spread over 60 acres (242,811 sq m) and rainwater used to accumulate in the temple tank. Overflows from the tank spilled into the Tirupathangal Eri and then into the Moongil Eri and finally into the Adyar creek.

In the year 2000, Mangalam Balasubramanian, a Pammal resident and President of Exnora International, an environmental service NGO, decided to mobilise local residents to come together and clean up the tank. This case study shows that it is possible to make ordinary citizens commit to protect their natural resources, chart a proactive path, with no help from the government.

This case study shows that it is possible to make ordinary citizens commit to protect their natural resources, chart a proactive path, with no help from the government

WHY: INDUSTRY, POPULATION AND NEGLECT

Over the years as Pammal became industrialised, more and more people came to settle here. The upkeep of the temple tank was neglected and the inlet drains leading to it were blocked. Rainwater, instead of flowing into the tank, would collect on the streets. The tank slowly deteriorated into a slushy, foul-smelling stagnant water body. It became a dumping ground for garbage and residents let their sewage into the tank. The tank was completely silted and its depth was reduced to just about 4 feet (1.2 m).

RENOVATION IN THREE MONTHS

The task of cleaning up was challenging. Earthwork for desilting and cleaning the debris of the tank covering an area of nearly 5 acres (20,234 sq m) had to be undertaken and then the tank bed had to be deepened. A door-to-door campaign for raising funds was launched. Schools, Rotary Clubs and individuals raised more than Rs 13 lakh. With active involvement of all citizens, the task was completed in a short span of about three months.

After cleaning and desiltation gates for inlet and outlet drains and a settlement tank with a natural filtration system was constructed around the tank. Finally the *bund* (or embankment) was strengthened and a wall was erected around the tank. The renovated tank was inaugurated in December 2001. The following summer itself, after the rains, the water level in the tank had come up to 10 feet (3 m).

The citizen's movement became more organised and came to be known as the Exnora Pammal Green, which is now responsible for maintenance. The temple staff supports citizens in this effort. Every summer, the tank is desilted and lime coating is applied for disinfection. A walkway has been created around the tank and trees have been planted around the walkway. Walkers pay Rs 10 as a monthly membership which is used for maintaining the area.

IMPACT

Groundwater in wells within a 5-7 km radius has improved. For instance, a nearby building, Sathsagh, had a dugwell with no water. Today, the well has plenty of water and people are able to access it by using a rope and bucket.

MANGALAM BALASUBRAMANIAN

Before 2001 – polluted, degraded

MANGALAM BALASUBRAMANIAN

December 2001 – cleaned and protected tank

System details
Area of tank: 5 acres (20,234 sq m)
Dimensions of the settlement tank: 200 ft x 300 ft x 10 ft
Cost: Rs 13.5 lakh
Year implemented: 2001

Designed and implemented by *Exnora Green, Pammal*

Revival of traditional step-well

NIZAMUDDIN BAOLI

NEW DELHI

Cleaning and revival of the 700-year old *baoli* (step-well) has been undertaken as a cooperative effort of several public and non-profit institutions with state-of-the-art technologies.

The Nizamuddin *baoli* was built about eight centuries ago (1321-22) and served as the water source for the Nizamuddin *dargah*, the mausoleum and shrine of the Sufi saint, Hazrat Nizamuddin Auliya. Located near the northern gate of the enclosure, the *baoli* is fed by underground springs and is a protected monument under the Archaeological Survey of India. It is said that the saint used a passage to access the *baoli* from the mosque within the *dargah* complex.

WHY: FILLED WITH SEWAGE

Despite being a protected monument the area around the *baoli* has been encroached upon and constructions have come up even on the walls surrounding it. The sewage from these settlements polluted the waters of the *baoli*. Water from the *wuzu* area (meant for ablutions, washing before prayers) of the mosque would also drain into the *baoli*.

Several non-profits and public bodies came together to clean the *baoli*

In July 2008, portions on the walls of the *baoli* collapsed, putting the constructions over the walls in danger. A conservation project covering the entire area was initiated by a number of government and non-governmental bodies and rejuvenation of the *baoli* was taken up as part of this project.

The Archaeological Survey of India (ASI), the Central Public Works Department (CPWD), the Municipal Corporation of Delhi (MCD) have been working in conjuction with the Aga Khan Trust for Culture (AKTC) and Aga Khan Foundation towards the restoration.

Extensive scientific analysis was conducted aimed at rebuilding and rejuvenating the *baoli*. State-of-the-art technologies such as Ground Penetrating Radar Survey (GPRS), high definition 3D laser scans and other geo-technical and structural assessments were used.


PHOTOS: AGA KHAN TRUST FOR CULTURE

The baoli was taken up for restoration in 2008

Desilting operation underway

WASTEWATER SEGREGATED

The first task was to clean out the *baoli* completely. The dirty water was drained out and the *baoli* desilted to its original depth 80 feet (24 m) below the ground level. Analysis of the water quality showed very high levels of *E. coli* indicating the entry of sewage into the *baoli*. The manual desilting of the *baoli* to clear hundreds of years of accumulated debris and sludge was a mammoth task involving nearly 8,000 man-days of work. As part of the project, housing on top of the wall had to be demolished and alternate accommodation given to the families. New sewer pipes were laid to divert sewage away from the *baoli* and a new system was constructed to keep water from the *wuzu* area from entering the *baoli*.

IMPACT

Water quality was tested once again after reconstruction work recording a dramatic drop in *E. coli* levels. The challenge is to prevent the *baoli* slipping back into a sewage and waste dump. To prevent such a situation the AKTC has been conducting awareness and education campaigns for people residing in the area. It remains to be seen if the *baoli* remains clean and keeps providing clean water.

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Traditional water harvesting

Residential

RESIDENCE OF ASHUTOSH BHATT

DHOBINI POL, AHMEDABAD, GUJARAT

The *haveli* of Ashutosh Bhatt boasts of a magnificient 200-year old *tanka* (underground water tank). Its storage capacity is about 302,833 litres (80,000 gallons). Even now, the Bhatt family stores harvested rainwater in this traditional *tanka* and uses the water for drinking and cooking.

WHY: WATER CRISIS ENCOURAGES REVIVAL

In recent years, with the increasing demand for water, the Ahmedabad Municipal Corporation and the citizens have turned to traditional wisdom. The *tankas*, part of almost every household in the city's *pols* (the walled city), can supply entire families with clean drinking water throughout the year.

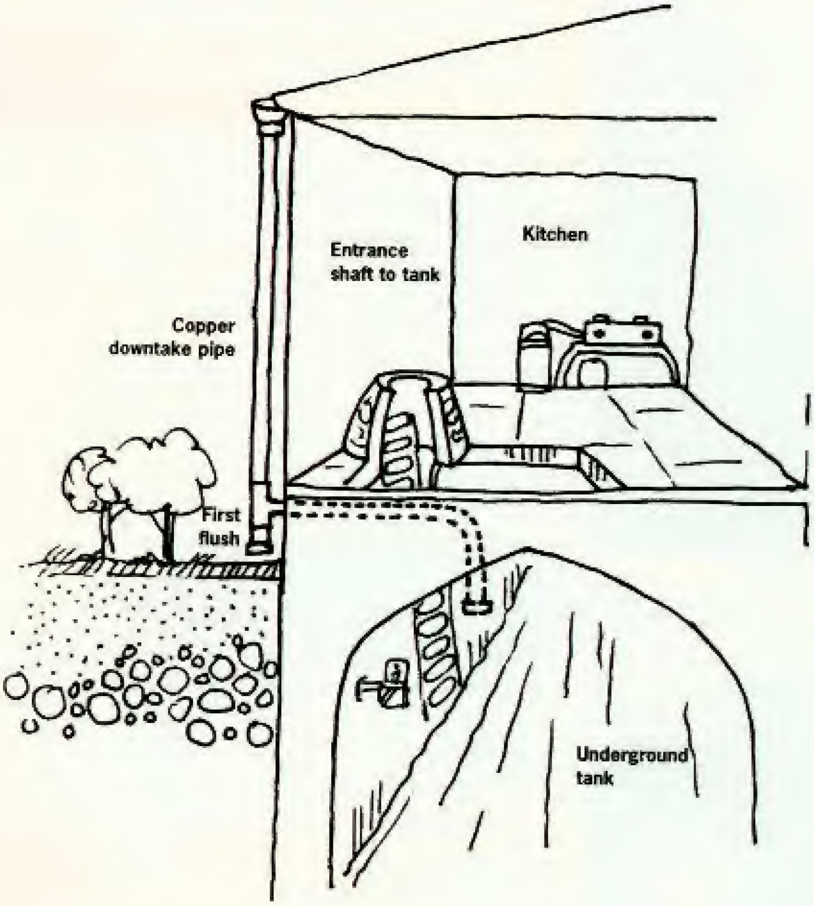
ASHUTOSH BHATT

The entrance shaft to the underground tank

ASHUTOSH BHATT

The underground sump for storage of rainwater

Rainwater can be supplied throughout the year, especially for flushing toilets



In pre-Independence days these *tankas* were sealed by the British to prevent freedom fighters from using these as hiding places. Over the years, as municipal water supply gained ground, people lost interest in these rainwater harvesting systems.

When the *tankas* were opened for rejuvenation by the heritage cell of the Corporation, after a gap of nearly fifty years, they found the water to be fresh and of high quality.

IN GOOD CONDITION

The *tanka* in the Bhat household can be reached through a small pyramid-like structure in the kitchen, which is 1 m in diameter, just wide enough to allow one person to descend through the opening. A flight of stairs leads into the tank. It is periodically accessed for cleaning and maintenance purposes.

Rainwater falling on the terrace is channelled into a copper pipe which branches into two outlets, one takes the water into the underground sump and the other to the waste drain. The first flush of rainwater is allowed to escape as stormwater. After the cap of the downtake pipe leading to the drain is closed, water flows into the tank.

Before the water enters the *tanka*, it is filtered through layers of charcoal, lime and pebbles.

The tank is free of algae and microbes since the interior of the tank is perpetually dark and the lack of light stops their growth. The lime plaster on the surface of the underground tank also ensures that they do not grow.

System details
Volume of underground tank: 302,833 litres (80,000 gallons)
Height of tank: 8 m
Length & width of tank: 4.6 m

Designed by *ancestors of Ashutosh Bhatt*
Maintained by *family of Ashutosh Bhatt*

SALAHUDDIN SAIPHY / CSE

Down the generations, grandmother and granddaughter drawing water from the tanka

SALAHUDDIN SAIPHY / CSE

Rainwater pipe from the second floor of the house leading to the tanka

SALAHUDDIN SAIPHY / CSE

Crystal clear water in the bucket drawn from the tanka

RESIDENCE OF AMARISH BHAI VAISNAV

JUNAGADH, GUJARAT

Amarish Bhai Vaisnav has a family of five. The elderly Vaisnavs are happy to live in their ancestral property, located in the older parts of Junagadh. Their son has bought a flat in a modern housing society, but are still not ready to shift there due to the water crisis they may have to face. "The new modern flats in Junagadh do not get drinking water for weeks at a stretch. In our old house we are at least sure of good quality drinking water from our *tanka*," says the eldest member of the house.

Their underground *tanka* can cater to all potable water requirements upto two years, even if there is no rain. It has a capacity of 60,000 litres.

HOW: FIRST FLUSH AND THEN FILTER

Traditional roofwater harvesting built with simple systems of first flush and filters are even today being used by people in Junagadh, Gujarat. Disinfection is done by adding lime (*chuna*) and used for all potable requirements.

IMPACT

The *tanka* serves this house well. On an average, eight buckets of water, of 5 litres capacity are taken out everyday for potable purposes.

Designed by *ancestors of Amarish Bhai Vaisnav*
Maintained by *family of Amarish Bhai Vaisnav*

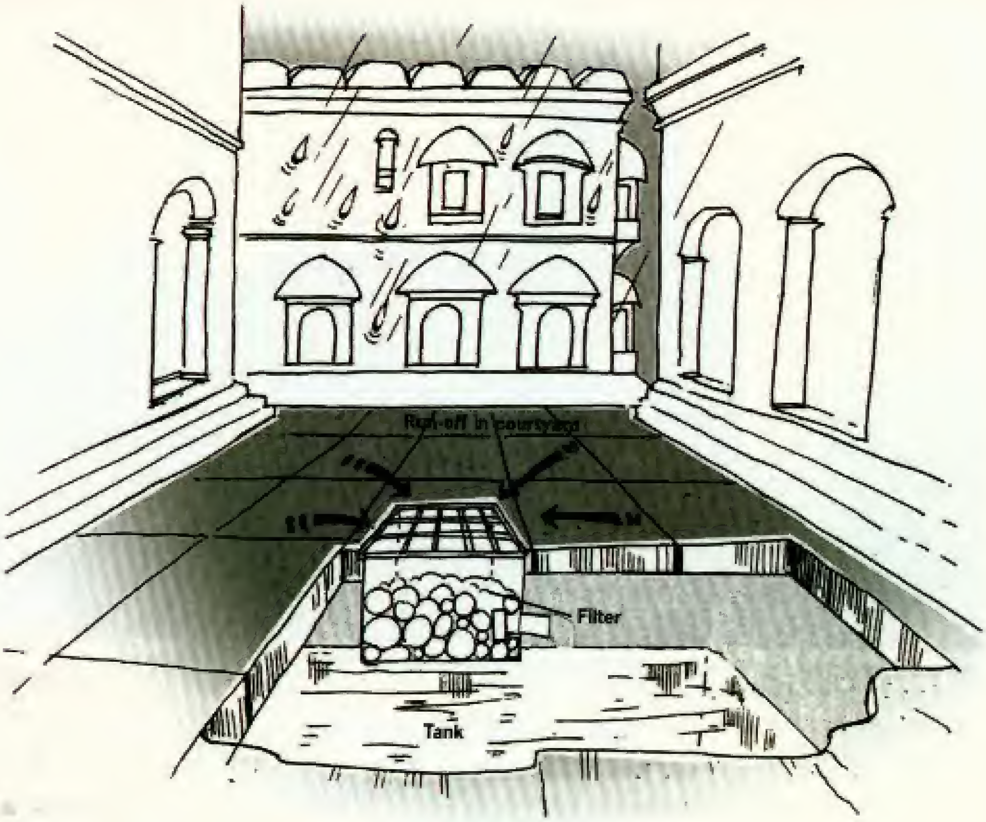
SALAHUDDIN SAIPHY / CSE

First flush: The left outlet is plugged with cloth during the initial rains. The first flush of rainwater flows into the other outlet which leads into a stormwater drain outside the house. Water is later diverted into the tanka

Traditional Indian fort

MEHRANGARH FORT

JODHPUR, RAJASTHAN



Built in the 18th century by the Rathore Rajput kings, the harvested water was used by the residents of the fort for drinking and cooking.

Jodhpur city in Rajasthan falls in the desert region of the country. The average annual rainfall is 325.5 mm and there are only 19 rainy days. Rainwater harvesting has been practised in this city from time immemorial. Traditionally, Jodhpur used every means to use rainwater and there were a variety of water harvesting systems – *tankas, talabs, baolis, kunds*.

The rulers of Jodhpur harvested rainwater on different catchments within the Mehrangarh fort and underground tanks stored the harvested rainwater. Even today, two such systems, the Daulat Khana *tanka* and the Janani Dyori *ka tanka*, constructed in the 18th century, provide drinking water among other uses. The rainwater from the roof and paved surfaces of the fort is filtered through pebbles and is then stored in these two tanks.

The Daulat Khana *tanka* has a capacity of 2.5 lakh litres and stores water harvested from the roof area and the Janani Dyori *ka tanka* has a capacity of 4.7 lakh litres and stores water from the paved surfaces. The water in this *tanka* is of very high quality and is used for drinking by the resident's of the fort.

Maintained by *the Mehrangarh Museum Trust*

Pre-Independence, British built

RASTRAPATI NIVAS

SHIMLA, HIMACHAL PRADESH

SUSHMITA SENGUPTA / CSE

The Rastrapati Nivas, formerly the Viceregal Lodge, houses the Indian Institute of Advanced Study

The Indian Institute of Advanced Study (IIAS) in Shimla is housed in the the Rastrapati Nivas, a heritage property and landmark of the town. Formerly known as the Viceregal Lodge, it was designed by British architect Henry Irwin and constructed in 1888. The building was designed with a rainwater harvesting system and the tanks are still in good condition and used even now.

Rainwater harvesting saves municipal supply. The stored rainwater is used for the extensive gardens

TIME-TESTED SYSTEM

The building has a rooftop area of 2,498 sq m. Rainwater is harvested from the rooftop and stored in a series of five cylindrical underground tanks linked to each other so that overflow of one passes into the next.

The roof of the lodge is sloped and tiled. Water from across the vast roof, the various cupolas, the different levels, is collected at a central point on the roof and passed through silt traps placed there. Then the water is diverted towards the downtake pipe. From here the water directly passes into the storage tanks.

Each tank is covered with a double-layered lid. The lower lid is slotted to act as another layer of filter to arrest silt from the surface run-off. The upper lid completely covers the tank opening.

According to the Central Public Works Department (CPWD) engineer responsible for the upkeep of the building, the roof is cleaned before the monsoon and the tanks monitored closely. Any leakage or other maintenance problems are addressed before the rains.

System details

Total rooftop area: 2,498 sq m

Storage systems (total capacity of 176,600 litres): 5 tanks

Year implemented: 1888

Designed by *Henry Irwin, architect*

Maintained by *Central Public Works Department*

IMPACT

The stored rainwater is used throughout the year for gardening. As the property has large gardens, substantial amounts of water are needed for their upkeep. The rainwater harvesting structure thus, saves on water from the municipal supply.

ROOFTOP WATER HARVESTING

AIZAWL, MIZORAM

Aizawl receives very high rainfall (2,049.7 mm) both from the south-west and north-east rainfall. Every other house of this hill town in North-east India has small but effective rainwater harvesting systems.

WHY: LITTLE RECHARGE, RAPID RUN-OFF

Because of the hilly terrain, there is rapid run-off and very little recharge. Villages are usually on the hilltops and water is available at the bottom of the valleys. People have to walk long distances to the rivers or springs in the valley to collect water.

A RAINWATER CULTURE

The British were the first to build rainwater harvesting systems in the town. Water harvesting became the norm and almost every house had a gutter to capture and direct rainwater to a small storage tank placed under the roof. This water was used for all purposes. As rainwater was available for most of the year, even small storage tanks were sufficient to provide water for all uses. Even today, common people use this system to meet their water needs.

A rainwater harvesting culture that began way before Independence is giving way to a culture of piped water supply actively promoted by the government

NOW, A PIPED WATER CULTURE

The government is replacing this simple, decentralised system with expensive piped water supply. A large tank that was made by the British to store rainwater for the public is being used today to store piped water from the river.

ANIL AGARWAL / CSE

Simple rainwater harvesting system consisting of a sloped roof, gutter and a storage tank

ANNEXURE 1
Information that you will need

1 CATCHMENT RELATED INFORMATION

1.1 Run-off coefficient for different types of catchment

Catchment	Type of material	Run-off coefficient
Roof	Tiles	0.8-0.9
	Metal	0.7-0.9
Paved area Driveway/courtyard, roads	Concrete	0.6-0.8
	Brick	0.5-0.6
Unpaved area garden, playground	10% sand	0.0-0.3
	Hard compact	0.2-0.5
	Lawns	0.1

Source: Pacey, Arnold and Cullis 1989, *Rainwater harvesting, the collection of rainfall and run-off in rural India*, Intermediate Technology Publications

1.2 Run-off coefficient for different roof types in India

Roof type	Run-off coefficient
Galvanised iron sheet	0.9
Asbestos sheet	0.8
Tiled roof	0.75
Concrete roof	0.7

Source: Manual on construction and maintenance of household-based rooftop water harvesting systems, report prepared by Action for Food Production for UNICEF

2 RAINFALL RELATED INFORMATION

2.1: Rainfall, rainy days and maximum rainfall intensity in different cities of India

Name of city	Annual average rainfall (mm)	Rainy days	Based on average of years	Maximum rainfall intensity (mm/hour)	Based on years
Ahmedabad	740.6	33.3	1971-2000	90	1969-2003
Aizawl	2244.7	117.1	1951-1980		
Allahabad	1017.7	48.6	1951-1980		
Amritsar	681.2	35.8	1951-1980	99	1969-2004
Aurangabad*	813.5	46.4	1981-2006	78	1969-2005
Bengaluru	974.5	58.4	1971-2000	72	1969-2004
Bhopal	1146.7	51.4	1951-1980	90	1970-2004
Bhubaneswar	1542.2	73	1951-1980	120	1969-2006
Chandigarh	1059.3	49.8	1951-1980		
Chennai	1266.9	57.1	1951-1980	87	1969-2005
Cherrapunji	11619.4	156	1971-2000		
Coimbatore	631	42.7	1951-1980	76	1969-2005
Darjeeling*	2323.2	98.9	1979-2005		
Dehradun	2315.4	84.6	1951-1980	101	1969-2005
Gangtok	3736.8	167.6	1971-2000		

Continued...

2.1 ...continued

Name of city	Annual average rainfall (mm)	Rainy days	Based on average of years	Maximum rainfall intensity (mm/hour)	Based on years
Goa	2932	100.1	1951-1980	130	1969-2005
Guwahati	1743.4	91.3	1971-2000	85	1969-2006
Gwalior	899	42.6	1951-1980		
Hyderabad	812.5	51	1951-1980	100	1969-2003
Indore	1008.3	48	1951-1980		
Jaipur	673.9	36.8	1951-1980	70	1969-2005
Jamshedpur	1508.5	77.5	1951-1980		
Jodhpur*	325.5	18.6	1980-2006	83	1971-2005
Kanpur*	804	39.7	1960-2005		
Kochi	3228.3	131.9	1951-1980		
Kolkata	1641.4	82.2	1951-1980		
Lucknow	1021.5	47.1	1951-1980	73	1969-2005
Ludhiana	752.3	36.7	1951-1980		
Madurai	837.9	45.2	1951-1980		
Mangalore	3620.8	112.1	1971-2000	93	1969-2004
Mumbai	2422.1	80.6	1951-1980	113	1969-2004
Mysore	857.8	58.4	1971-2000		
Mussoorie*	1933.9	86.2	1981-1992		
Nagpur	1146.7	51.4	1951-1980	79	1969-2005
New Delhi	797.3	39.1	1951-1980	112	1969-2005
Patna	1003.4	48.6	1951-1980		
Port Blair	2917.5	130.8	1951-1980	122	1969-2003
Puducherry	1263.5	53.1	1951-1980		
Pune	721.7	49.9	1951-1980	66	1969-2004
Puri*	1521.9	63.5	1981-2006		
Raipur	1288.8	62.3	1951-1980		
Rajkot	576.6	28.3	1971-2000	116	1969-2003
Ranchi	1462.8	79.2	1971-2000		
Shillong	2167.4	112.7	1971-2000		
Shimla	1424.8	84.8	1951-1980		
Srinagar	703.6	55.6	1971-2000	40	1970 -2005
Thiruvananthapuram	1827.7	99.7	1951-1980	77	1969-2003
Udaipur	651.7	34.9	1951-1980		
Varanasi	1025.4	48.1	1951-1980	100	1970 -2005
Vishakapatnam	968.8	52	1951-1980		

Source: http://www.imd.gov.in/section/climate/, as viewed in March 2012
Notes: *Indian Meteorological Department, Pune
For rainfall intensities : N R Deshpande, A Kulkarni and K Krishna Kumar 2011, 'Characteristic features of hourly rainfall in India', *International Journal of Climatology*

3. HYDRO-GEOLOGICAL INFORMATION

3.1: Soil related information

3.1.1: Infiltration rate for different types of soils

Soil type	Infiltration rate(mm/hour)
Highly clayey soils	Below 2.5
Shallow soils, clay soils, soils low in organic matter	2.5 - 12.5
Sandy loams, silt loams	12.5 - 25.0
Deep sands, well aggregated soils	Above 25

Source: Anon 2007, 'Manual on artificial recharge of groundwater', Central Ground Water Board, New Delhi

3.1.2: Permeability of soils

Type of soil	Permeability (cm/hour)
Sand	5
Sandy loam	2.5
Loam	1.3
Clay loam	0.8
Silty clay	0.25
Clay	0.05

Source: Training manual on soils, Chapter 9, 'Permeability of soils, Food and Agriculture Organisation', ftp://ftp.fao.org/fi/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e09.htm, as viewed in March 2012

3.1.3: Porosity of soils

Soils	Porosity
Gravel	25 – 40%
Sand	25 – 50%
Clay	40 – 70%

Source: Freeze and Cherry 1979, http://www.potomacriver.org/2012/drinkingwaterdocs/ww_wksp_pres/Basic_Hydrology_Part2.pdf, as viewed in March 2012

3.1.4: Size classes of soils

Soil	cm
Fine gravel	0.2-0.6
Medium gravel	0.6-2.0
Coarse gravel	2-6
Stones 6-20	2-6
Boulders	20-60
Large boulders	60-200

Source: Anon 2006, *Guidelines for soil description*, Food and Agriculture Organisation of the United Nations, Fourth Edition, ftp://ftp.fao.org/agl/agll/docs/guidel_soil_descr.pdf, as viewed in March 2012

3.1.5: Soil types of India and their suitability for recharge

Type of soil	Where found	Key properties	Suitability for groundwater recharge
Red soil	Andhra Pradesh, Assam, Bihar, Goa, Parts of Kerala, Maharastra, Karnataka, Tamil Nadu and West Bengal	Red in colour. Light texture and porous	Suitable
Laterite soil	Summits of hills of Deccan Karnataka, Kerala, Madhya Pradesh, Ghat regions of Odisha, Andhra Pradesh, Maharastra, West Bengal, Tamil Nadu and Assam	Light texture and porous Yellow in colour	Suitable
Alluvial soil	Indo-Gangetic plains, Brahmaputra valley and almost all states of North and South	Sandy loam to clay loam with loose structure. Light grey colour to dark colour	Very good
Black soil	Maharastra, Madhya Pradesh, Gujarat and Tamil Nadu	Poor free drainage. Dark grey to black colour with high clay content.	Not suitable
Desert soils	Haryana, Punjab, Rajasthan	Sandy to loamy fine sand with brown to yellow brown colour	Very good

Source: T D Biswas and S K Mukherjee 1994, *Textbook of Soil Science*, Second Edition, Tata McGraw Hill

3.2: Rock related information

3.2.1: Infiltration characteristics of rocks

Parameter	Type of rock
Rocks that permit infiltration	Porous rocks: (Sandstone, chalk, shale) which contain pores
	Pervious rocks: (Carboniferous limestone, marble) which have cracks or joints through which water can infiltrate
Rocks that permit some infiltration	Fractured, fissured, weathered (basalt, quartzite, gneiss, slate, schist)
Rocks that permit no infiltration	Massive rocks (granite, basalt) that are impervious

Source: Anon 2007, 'Manual on artificial recharge of groundwater', Central Ground Water Board, New Delhi

3.2.2: Porosity of rock materials

Rocks	Porosity
Limestone, dolomite:	5 -50%
Karst:	5 -50%
Sandstone:	5 -30%
Shale	:0 -10%
Crystalline rock:	0 -10%

Source: Freeze and Cherry 1979, http://www.potomacriver.org/2012/drinkingwaterdocs/wv_wksp_pres/Basic_Hydrology_Part2.pdf, as viewed in March 2012

4. PHYSIOGRAPHIC INFORMATION

4.1: Suitability of rainwater harvesting structures based on physiography

Parameter	Type of terrain
Areas more suited for storage	Hilly areas are more suited for storage structures as the recharged water is likely to travel down to the valley.
	Coastal areas: Where the groundwater is shallow and saline, more suitable for storage.
	Desert areas: Low rainfall that may be absorbed by the thick sandy layer.
Areas suited for storage or recharge	Plains are suited for both recharge and storage.

Source: Centre for Science and Environment, New Delhi

5. DESIGN RELATED INFORMATION

5.1 Rainwater harvesting potential (ready reckoner)

Rainfall (mm)	250	350	450	550	650	750	850	950	1050	1150	1250
Water harvesting potential at 0.8 run-off coefficient (kilo litre)											
Rooftop area (sq m)											
100	20	28	36	44	52	60	68	76	84	92	100
200	40	56	72	88	104	120	136	152	168	184	200
300	60	84	108	132	156	180	204	228	252	276	300
400	80	112	144	176	208	240	272	304	336	368	400
500	100	140	180	220	260	300	340	380	420	460	500
600	120	168	216	264	312	360	408	456	504	552	600
700	140	196	252	308	364	420	476	532	588	644	700
800	160	224	288	352	416	480	544	608	672	736	800
900	180	252	324	396	468	540	612	684	756	828	900
1000	200	280	360	440	520	600	680	760	840	920	1000

Source: Anon 2007, *Manual on artificial recharge of groundwater*, Central Ground Water Board, New Delhi

6. WATER USE

6.1. Central Public Health and Environmental Engineering Organisation (CPHEEO) norms

Parameter	Litres/person/daily
Drinking	3
Cooking	4
Bathing	20
Flushing (toilets)	40
Washing clothes	25
Washing utensils	20
Gardening	23
Total	135

Source: Central Public Health and Environmental Engineering Organisation (CPHEEO), Union ministry of urban development, Government of India

6.2 Water use for a family of 5/day based on informal citizens' survey

Activity – Low end use	Unit usage/person	Litres
Bathing (15 litres/bucket)	(2 buckets/person)	150
Brushing teeth with the tap off (5 persons)	1 litre/person	5
Washing clothes	Per day	120
Car washing using a bucket	Per day	10
Flushing toilet (6 litres/flush)	5 times/person	150
Gardening with bucket (15 litres/bucket)	(4 buckets)	60
Drinking & cooking	6 litres/person	30
Washing utensils (twice a day)	50 litres/wash	100
Mopping (with bucket)	Per day	20
Personal hygiene	(6 litres/person)	30

Source: Centre for Science and Environment, New Delhi

ANNEXURE 2
Noting down information for your RWH sysrtem

RAINWATER HARVESTING SYSTEM
Information booklet

Name of person: ....

Type of project: ☐ Residential ☐ Institutional ☐ Industry ☐ Commercial ☐ Other

Name of building/project: ....

Address: ....

....

....

City.. PIN..............................

State..

Phone..

Email..

1. WATER DEMAND PROFILE

Type of building*	Purpose	No of users	Water used/day (litres)	Water used/year (kilolitre)
	Drinking			
	Cooking			
	Bathing & personal hygiene			
	Toilets			
	Washing utensils			
	Washing clothes			
	Household cleaning			
	Car wash			
	Gardening			
	Process use			
	Other			

Notes: *Residential, industrial, school, institutional, hospital, educational and others

ANNEXURES

2. SOURCE OF WATER

Source	Number	Quantity of water used (monthly) (kilo litre)	Purpose used for*	Quality of water available**	Monthly expenses incurred (Rs)
Municipal Supply (of hours supply/day/week)					
Groundwater (of hours of pumping/day/week)					
Working borewells					
Tanker supply (of tankers/week)					
Other source (Pls specify: Eg Pond)					
Total					

Notes: *P – potable use; N – non potable use; G – gardening, **satisfactory / not satisfactory (specify presence of smell, mud, bacteria, iron, flouride, nitrate, arsenic etc, if any)

3. CATCHMENT AREA DETAILS

Total area of plot =						
Type	**Description**	**Number**	**Length (m)**	**Breadth (m)**	**Area (sq m)**	**Material of catchment***
Roof (a)	Flat					
	Sloping					
	Total A1					
Paved area (b)	Driveway/courtyard					
	Total A2					
Unpaved area (c)	Lawn/ground					
	Total A3					
	GRAND TOTAL (a+b+c)					

Notes: *C: cement concrete; T: tiles; M: metal, GI sheet; A: asbestos

4. RAINFALL DATA DETAILS

S No	Name of meteorological station	
1	Average annual rainfall (mm)	
2	Peak hourly rainfall (intensity) (mm/hour)	
3	Number of rainy days (No)	
4	Number of dry days (No)	
5	Spell of the scarcity period (No)	

5. GEOLOGICAL AND HYDRO-GEOLOGICAL INFORMATION

Description	Site-specific information		
Type of soil (tick) ☐ Sandy ☐ Clayey	☐ Loam ☐ Any other (specify)________		
Type of rock (tick)	Fractured	Massive	Weathered
Groundwater table level (m bgl)	(10 years ago)	(5 years ago)	(current)
Depth of porous strata (m bgl) (from borehole log)			
Amount of groundwater withdrawals kilolitre/day			
Yield of borewells (litres/hour)			

6. WATER DEMAND

a	Number of persons		(number)
b	Per capita water consumption		litres/day
c	Total water requirement for 1 day		a*b
d	Number of scarcity days		(number)
e	Therefore total water demand for scarcity period in the year		c*d
f	Existing water supply		litres/year
f 1	Municipal supply	cum/day	cum/year
f 2	Groundwater	cum/day	cum/year
	Total existing supply		
g	Net demand to be fulfilled from rainwater harvesting		e-f

ANNEXURES

ANNEXURES 3

Knowledge bytes on rainwater harvesting

The water cycle: This is the continuous cycle of movement of water within the earth. Water evaporates from the earth, condenses in the atmosphere, falls as rain and finally reaches the ocean as rivers, coastal run-off and groundwater flows. The entire process is driven by the energy of the sun.

Rain gauge: This is an instrument that measures rainfall. The tipping bucket rain gauge is one of the commonest used, consisting of a 'bucket' with two tiny compartments mounted on a fulcrum (balanced like a see-saw) of equal capacity. This assembly is located underneath the rain (precipitation) collector, which funnels it into the bucket. Water is collected in one compartment and as it becomes overbalanced, it tips over. Rainwater is now collected in the other compartment, which follows the same procedure. The time of each tip is recorded in real time using data loggers. A good tipping bucket instrument records volumes of 0.1-0.5 mm/tip.

Rainfall intensity: The intensity of rainfall is normally inversely proportional to its duration. When the rainfall intensity is greater there is also greater run-off. It is usually measured in millimetres or inches per hour. [Rainfall intensity = Volume of rainwater/Duration of rainfall].

Groundwater: This is water found beneath the earth's surface in soil pore spaces and in the fractures of rock formations. It can be found in sand, gravel, silt, clay, sedimentary rocks, limestone beds or even in impermeable rocks such as granite when such rocks are weathered

An early rain guage

The earliest record of the measurement of rainfall through rain gauges is found in Kautilya's Arthasastra (400 BC). In Kautilya's words, "In front of the store house, a bowl (*kunda*) with its mouth as wide as an *aratni* (about 18 inches) shall be set up as a rain gauge." The rain gauge was called *varshaman*. Kautilya set up a network of rain gauges across the country.

Dugwells in ancient India

Excavations in Mohenjodaro and Harappa are proof of how advanced ancient Indians were in the use of groundwater as far back as 3,000 BC. It is said that there were more than 700 wells in Mohenjodaro, some of them fifteen metres deep, built with special trapezoid bricks (to prevent collapse by the pressure of the surrounding soil), and maintained for several centuries. Many of these wells were found in private houses. Although the Indus river cut across the city, it is clear that river water was not used for drinking purposes. Rather, it took in all the sewage. Drinking water was taken from wells.

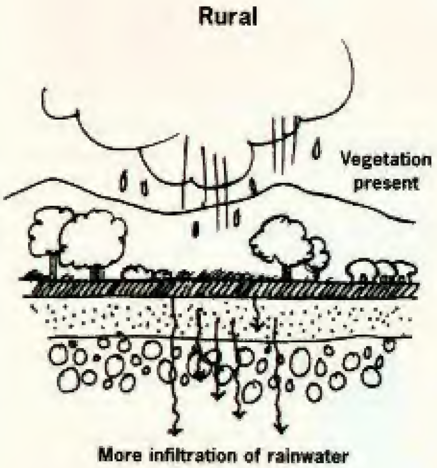
or fractured. On the surface of the earth, it can be seen in wells and as springs. The water percolates downward in response to gravity or differences in pressure.

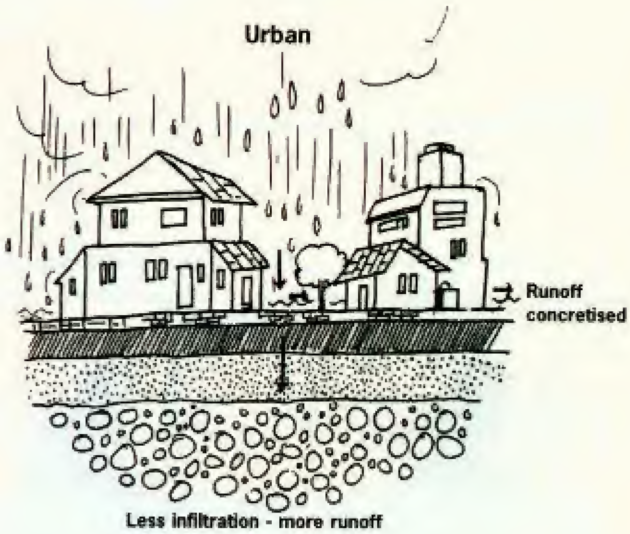
Infiltration: Is the entry of rainfall or surface water into the soil at the ground surface.

Infiltration rate: The maximum rate at which any soil is capable of absorbing water under given conditions is called the infiltration rate. It is high at the beginning of the rainfall session (50 mm/hour) and decreases as rain continues at a steady rate (15-20 mm/hour).

The infiltration rate depends upon:
- the duration and intensity of rainfall,
- weather characteristics and soil conditions,
- vegetal cover,
- initial wetness,
- depth of groundwater table,
- land use.

In urban situations where vegetation has been removed and replaced by impermeable surfaces, there is less infiltration and more run-off into stormwater drains (see below).



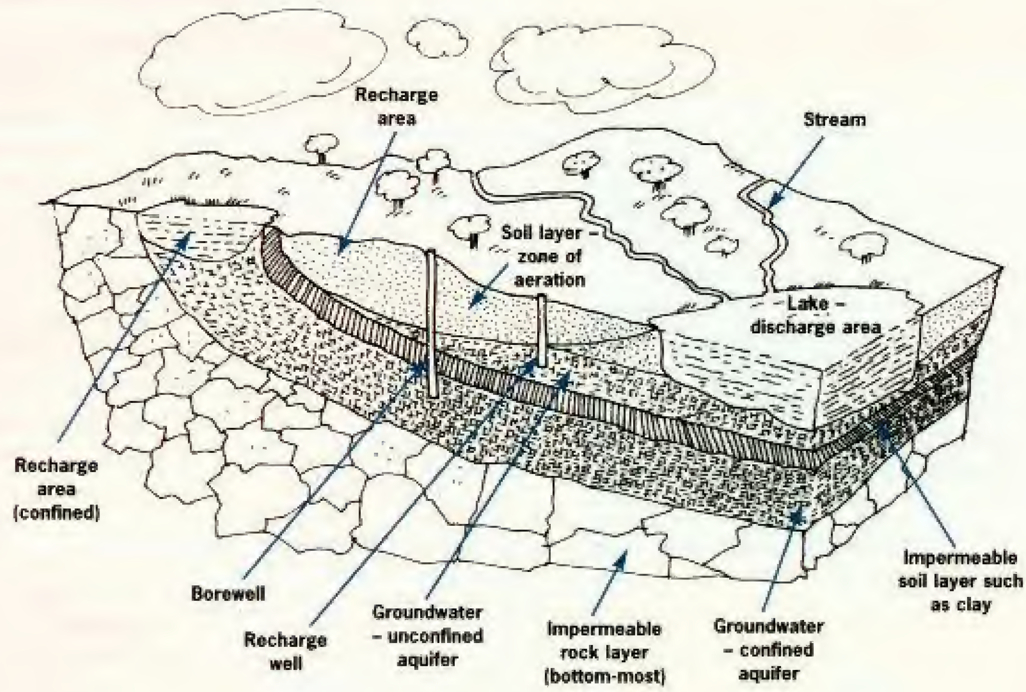


Percolation: The process by which water, after infiltration into the soil, moves downward or laterally through openings or fissures or fractures within the rocks in response to gravity or differences in pressure. If there is an impermeable layer of rock below, then the water moves laterally and joins the stream flow. When there is no impeding layer, the water percolates into the ground and builds up the groundwater table.

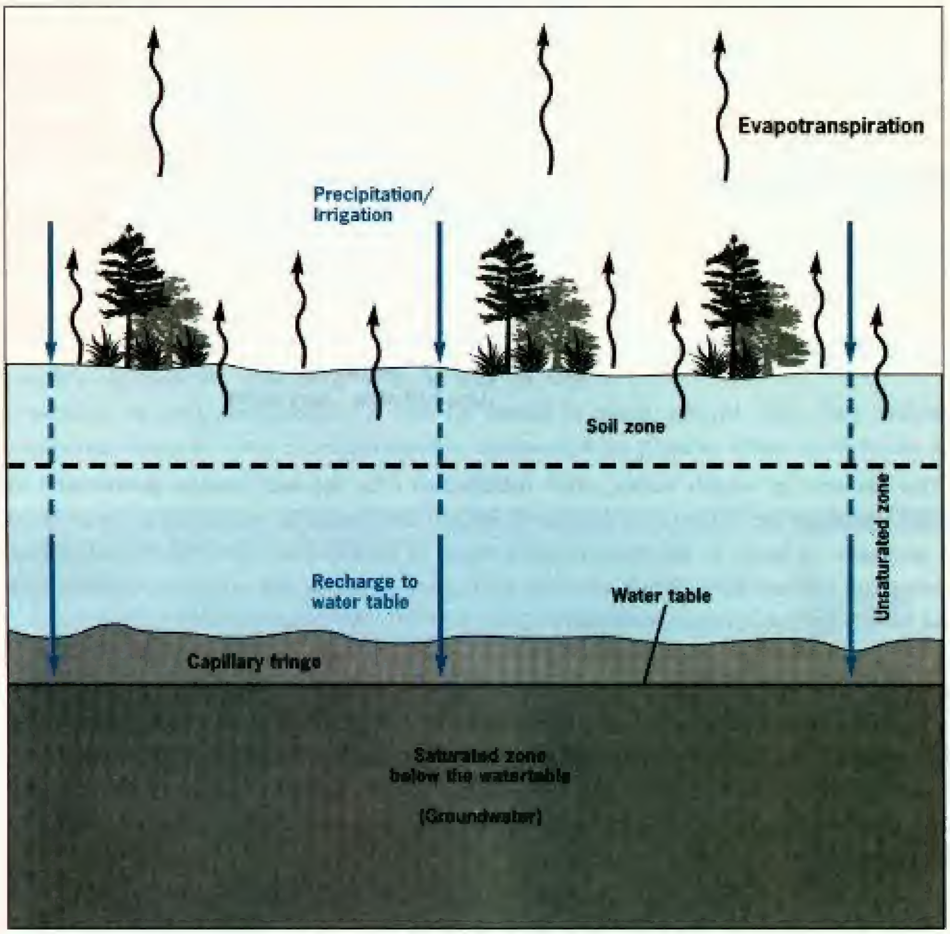
Groundwater zones: The Vadose zone (or unsaturated zone) is the layer of soil that contains both water and air. The top portion of this zone is called the root zone and contains the roots of plants, animal and worm burrows. Below that is the capillary zone, followed by the saturated zone, where all the open pores are filled with water. The surface of the saturated zone is known as the water table. The availability of groundwater depends on the ability of rocks and soils to receive, hold and yield water.

Groundwater flow: Groundwater moves from areas of recharge – from rain or snow – to areas of discharge, such as springs, lakes or oceans. It moves slowly, often only inches in a day, and may take years to reach its natural discharge zone. Aquifers are not only storage zones but pathways for the flow of groundwater.

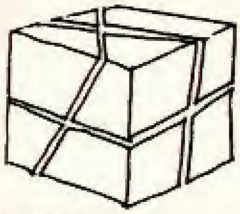
Aquifer



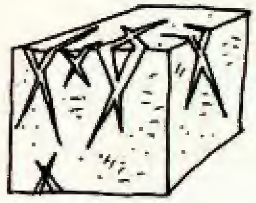
Soil zones



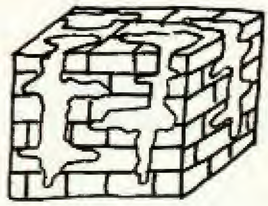
Fractured aquifers



Fractures in basalts

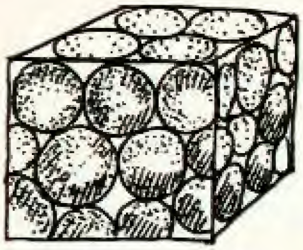


Fractures in granite

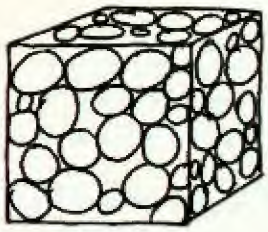


Caverns in limestone

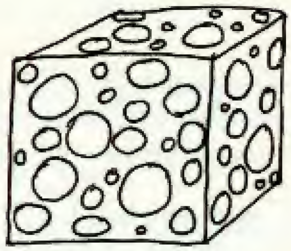
Properties of aquifers



Well sorted porous grains



Well sorted



Poorly sorted

Recharge and discharge: There is a constant two-way movement within the groundwater. It is recharged by rainfall and river and lake waters. Groundwater is also discharged into wells, rivers, lakes, wetlands and oceans.

Aquifer: An aquifer is underground rock or soil that stores large amounts of water without loss through evaporation or pollution. It yields water and allow movement of water under certain conditions.

Fractured aquifers: These are rocks in which groundwater moves through cracks, joints or fractures in otherwise solid rock. Examples of fractured aquifers include granite, basalt and limestone.

Depletion of aquifer: When the extraction of water exceeds the recharged volume of water, aquifers get depleted. This overuse of the groundwater is called groundwater mining.

What makes a good aquifer?
The properties of the materials that make up the aquifer as well as that of the aquifer itself are important considerations for recharge as they determine how quickly and in what direction the water will move through the aquifer. The properties of an aquifer will depend on the nature of the soil and the nature of rocks that make up the aquifer.

Aquitards: Zones that either restrict or completely block the movement of groundwater between aquifers and are made up of layers of clay or non-porous rock with low hydraulic conductivity. An aquitard that is completely impermeable is called an 'aquiclude' or 'aquifuge'.

Unconfined aquifers: An unconfined aquifer is exposed to the surface, but has an underlying confining layer. It has both a saturated zone as well as an unsaturated zone. The top of the saturated zone is called the 'water table' which is subject to atmospheric pressure. It receives recharge directly from the surface.

Confined aquifers: These are overlain and underlain by impermeable rock mass. The confined aquifer receives recharge from distant sources. The ability of the aquifer to hold water of a confined aquifer is much lower than that of an unconfined aquifer.

Consolidated aquifers: These are made up of material that is closely packed or cemented together such as limestone, fractured rock or soft sandstone.

Unconsolidated aquifers: These are made up of loose material such as sand, pebbles and gravel. In hilly terrain, aquifers will usually be unconsolidated alluvium.

Porosity: The number of pores per unit volume of soil or rock is called porosity. The porosity of a rock or soil determines how much water can be held in it. Soil with a large number of spaces between particles has a high porosity.

Permeability: Permeability defines the ability of soil or rock to transmit the flow of water. Permeability depends on the number of spaces and how well they are interconnected. It also depends on the size and shape of grains, their uniformity and distribution.

Very high permeability may mean that there will be high discharge of stored water and hence not suitable for storing water in the aquifer. Moderate permeability is ideal for recharging the aquifer for use at a later time. Alluvium, sand dunes, fractured or weathered rocks are good for recharging the aquifer. Porosity together with permeability makes a good aquifer.

Thickness and area of the aquifer: The greatest volume and rates of recharge will be obtained when the underlying strata consist of thick formations of porous and permeable sand or gravel or porous or cavernous rocks.

Soil texture: Soil texture is determined by the varying proportions of differently-sized particles. The main types of soil textures are sand, loam, silt and clay.

ANNEXURE 4

A resource list

AHMEDABAD

Raj Irritech Pvt Ltd,
Plot No. 427, Road No.10, GIDC Kathwada,
Phase II, Ahmedabad – 382 430.
Gujarat.
Phone : 079 22901634/36,
http://www.rajirritech.com/raj-group.html
(Contact for pop-up filters)
Chapter 8: Filter systems

Ashutosh Bhatt,
Dhobini Pol,
Ahmedabad,
Gujarat.
Phone: 079 22142314
(Traditional water harvesting system)
Chapter 16: Case study: Residence of Asutosh Bhatt

Vipul Shah,
Secretary,
Bimanagar Cooperative Housing Society,
Satellite Road, Ahmedabad,
Gujarat.
(Recharge of groundwater)
Chapter 11: Case study: Bimanagar Cooperative Housing Society

PRAVAH,
G-2 Raksha Apartment,
Himatlal Park Road,
200 Azad Society,
(Near Satellite Road),
Ahmedabad – 380 015
Gujarat.
Phone: 079 26762590, 26763984
(Recharge of groundwater)
Chap 11: Case study: Bimanagar Cooperative Housing Society

Centre for Integrated Development,
1 Neelgagan Tower, Management Enclave,
Vastrapur, Ahmedabad – 380 015.
Gujarat.
Phone: 91 79 40034739, Mobile: 9426104739
E-mail: cfidahmedabad@yahoo.com
(Recharge of groundwater)
Chapter 11: Case study: Bimanagar Cooperative Housing Society

BENGALURU

S. Vishwanath,
Rainwater Club,
1022, 6th Block, 1st Floor, HMT Layout,
Vidyaranyapura Main Road,
Vidyaranyapura,
Bengaluru – 560 097,
Karnataka.
Phone: 080 41672790
http://www.rainwaterclub.org
(Contact for Varun filters)
Chapter 8: Filter systems

Rainy Filters,
#648, 11th Cross, 7th Block, Jayanagar,
Bengaluru – 560 082.
Phone: 080 26766252
Website: www.rainyfilters.com
(Contact for Rainy filters)
Chapter 8: Filter systems

A R Shiva Kumar,
Senior Fellow and Principal Investigator – RWH,
Karnataka State Council for Science and Technology,
Indian Institute of Science,
Bengaluru – 560 012.
Phones: 080 23341652, 23348848, 23348849
Website: http://kscst.org.in/rwh.html
(For information on pop-up filters)
Chapter 8: Filter systems

John Fowler (India) Pvt Ltd,
Plot No 6 & 6P,
Bommasandra Industrial Area,
Hosur Road,
Bengaluru – 560 099, Karnataka.
Phone: 080 27836794
E-mail: jfil@vsnl.com
(Industrial unit, maintaining groundwater levels)
Chapter 13: Case study: John Fowler India (P) Ltd

Dr G G Chandankeri
Technology Informatics Design Endeavour (TIDE)
No : 19, 9th cross, 6th main
Malleswaram, Bangalore - 560 003
Phone: 080-23315656, 23462032
Website: www.tide-india.org
(Industrial unit, maintaining groundwater levels)
Chapter 13: Case study: John Fowler India (P) Ltd

Jayawanth Bharadwaj,
Rainbow Drive
Sarjapur Road
Bengaluru, Karnataka.
Phone: 9845831499
E-mail: jayawanth_b@hotmail.com
(Harvesting using stormwater drains)
Chapter 11: Case study: Rainbow Drive

Biome Environmental Solutions Pvt Ltd
No 1022, VI Block, HMT Layout,
Vidyaranyapura,
bengaluru – 560 097.
Phone: 080 41672790, 080 23644690
E-mail: water@biome-solutions.com
(Harvesting using stormwater drains)
Chapter 11: Case study: Rainbow Drive

BHOPAL

Brijesh Namdeo,
AMBER,
134, Mandakini Society
Kolar Road, Bhopal 462042
Madhya Pradesh
Phone: 9977003476
(Contact for Amber filters)
Chapter 8: Filter systems

M K Khanna,
Secretary, Priyadarshini Heights Residents Association,
F 2, Priyadarshini Heights,
G-3, Gulmohur Colony,
Bhopal,
Madhya Pradesh.
Phone: 0755 4291142
(Recharge of groundwater in absence of municipal supply. Put a stop to tanker supply in multi-storeyed apartment complex)
Chapter 11: Case study: Priyadrashini Heights

BHUBANESWAR

Ruchika Social Service Organisation (RSSO)
3731/A Sriram Nagar, Samantarapur
Bhubaneswar – 751 002
Odisha
Phone: 0674 2340746, 2340583
(No municipal supply, slum area))
Chapter 14: Kargil & Suka Vihar

CHENNAI

R Ramani,
1050, 41st Street,
TNHB Colony,
Korattur,
Chennai – 400 080,
Tamil Nadu.
Phone: 044-26523310
ramani5343@yahoo.com
Chapter 10: Quality of rainwater

The Principal,
SISHYA,
New No 2, Padmanabha Nagar,
Adyar, Chennai – 600 020,
Tamil Nadu.
Phone-91-44-24912652
E-mail: sishya@sishya.com
(Recharge and improvement of quality of groundwater in school)
Chapter 12: Case study: Sishya

Mangalam Balasubramaniam,
Exnora Green Pammal, No 14, 7th Street,
Sri Sankara Nagar, Pammal,
Chennai – 600 075,
Tamil Nadu.
Phone: 09444392970
Email: mangalam_balasubramanian@yahoo.com
(Revival of tank, citizen's efforts)
Chapter 15: Arkeeswarar-Suriammam Temple Tank

DARJEELING

The General Manager,
Hotel Cedar Inn,
Cedar Inn, Dr Zakir Hussain Road,
Darjeeling – 734 101,
West Bengal.
Phone: 0354 2254446
E-mail: cedarinn@satyam.net.in
(Harvested rainwater mainstay for all non-potable uses)
Chapter 13: Case study: Hotel Cedar Inn

DEWAS

Rajneesh Londhey,
Vinayak Water Solutions,
190-C Kalani Bagh, AB Road,
Dewas – 455 001.
Madhya Pradesh.
Phone: 9893700410
E-mail: vinayakwatersolution@gmail.com
(Contact for Vinayak filters)
Chapter 8: Filter systems

GADAG

Gopal Krishna Acharya (Archak),
Shree Veeranarayana Temple,
Agrahar,
Gadag – 582 101,
Karnataka.
Phone: 8372235129
(Quality of well water has improved and is used for all ritual purposes)
Case study: Sri Veer Narayana Temple

GURGAON

Rakesh Goyal
Manager, Safety and Environment,
Honda MotoCorp,
69th KM stone, Delhi Jaipur Highway,
Daruhera – 122 100,
Rewari, Haryana.
Phone: 01274 242131135, 24329295
(Maintaining groundwater levels with extensive network of rainwater harvesting structures at industrial unit)
Chapter 13: Case study: Hero MotoCorp

HYDERABAD AND SECUNDERABAD

Dr M M Sharma,
19, Hastinapur Colony,
Near Sainikpuri Post Office,
Secunderabad – 500 094,
Andhra Pradesh.
Phone: 040 23296161 extn 2170
Chapter 6: Storage

Ms Babita M. Ingewar
Manager, P and A
Cygnus Microsystems (P) Limited,
93 Phase II, IDA, Cherlapally,
Hyderabad – 500 051.
Andhra Pradesh
Phone: 040 27261326
E-mail: babita@cygnusmicro.com
Chapter 5: Preparing your budget

INDORE

Dr V N Shroff
17, Lala Ramnagar, Indore,
Madhya Pradesh.
Phone: 9425900896
(Recharge completely reversed decline of groundwater)
Chapter 11: Case study: Farmhouse of V N Shroff

Mrs Omprakash Sharma
W A-10/Scheme No 94, Ring Road East,
Pipliyakumar Circle, Dewas Nallah,
Indore – 452 010,
Madhya Pradesh.
Phone: 0731- 4064864-66
(Using stored rainwater with care has stopped tanker water supply)
Chapter 11: Case study: Residence

JAMSHEDPUR

The Principal,
Kerala Public School,
Road No 17, Jawahar Nagar,
Mango, Jamshedpur – 832 110.
Phone: 2462458, 653341.
(Recharge of defunct well)
Chapter Case study: Kerala Public School

JODHPUR

Dr Rajesh Kumar Goyal, Sr Scientist,
Central Arid Zone Research Institute,
Jodhpur – 342 003, Rajasthan.
Phones: 0291 2788789, 9474470251
(Farm for research purposes, needs high quality of water for plants)
Chapter 12: Case study: Central Arid Zone Research Institute

Kr. Karni Singh,
Mehrangarh Museum Trust,
Mehrangarh Fort,
Jodhpur,
Rajasthan.
Phone: 9414410552
(Traditional water harvesting system)
Chapter 16: Case study: Mehrangarh Fort

JUNAGADH

Amrish Bhai D Vaishnav,
Old Nagar Wada,
Hethan Falia,
Junagadh, Gujarat.
(Traditional Water Harvesting System)
Chapter 11: Case study: Residence of Amrish Bhai Vaishnav

Unit Manager,
CMSU – WASMO,
Junagadh,
Gujarat.
Phone: 0285 2654105
E-mail: jdh.dwsc@gmail.com
(Drinking water)
Case study: Drinking water (Institution)

KOCHI

Community Health Centre
Government Hospital
Angamaly PO
Kochi
Kerala 683542
Phone: 0484 2455950
(Drinking water)
Chapter 12: Case study: Angamaly Government Hospital

Peter Thettayil,
Executive Director
The Andhyodaya
MC Road, Angamaly 683572
Ernakulam Dist.
Kerala
Phone: 0484-2453548,3254881 , 09388607010
andhyodaya@gmail.com
(Drinking water)
Chapter 12: Case study: Angamaly Government Hospital

St Mary's Church,
Korambadam,
Kadamakudi,
Kochi.
(Rainwater used for potable purposes)
Chapter 12: Case study: St Mary's Church

KOLKATA

Arvind Sarkar, Mall Incharge
Gariahaat Mall
Site office, Parking basement
Jamir Lane, Ballygunge
Kolkata – 700019
West Bengal
Phone: 033-24613502, 9830391162
(Used for airconditioning cooling systems)
Chapter 13: Case Study: Gariahaat Mall

Ranjit Gupta
Interdesign, 220/2, Panditia Road Extn.
Kolkata-700029
West Bengal
Phone: 033-24660625
E-mail: ranajit@cal.vsnl.net.in
(Used for airconditioning cooling systems)
Chapter 13: Case Study: Gariahaat Mall

N K Kanodia,
38A/1, New Road,
Alipur, Kolkata,
West Bengal.
(Used for laundry in residence)
Chapter 11: Case study: Residence of NK Kanodia

Dr Mohit K Ray,
Vasundhara,
10 Ssecond Road, Eastern Park,
Park Santoshpur,
Kolkata-700075, West Bengal.
Phone: 033 24165389
E-mail: mrsg@cal2.vsnl.net.in

(Revival of lakes)
Chapter 15: Case study: Baghajatin & Kajipukur lakes

Asis Sarkar,
Secretary,
Baghajatin Lake Unnayan -O-Tran Samity,
A/127/1 Baghajatin Pally,
Kolkata – 700 092.
West Bengal
(Revival of lakes)
Chapter 15: Case study: Baghajatin & Kajipukur lakes

A R Chakraborty,
Treasurer,
Kaji Pukur Unnayan Samity,
A/32/2 Baghajatin Pally,
Kolkata – 700 092.
Phone: 033 24127839
(Revival of lakes)
Chapter 15: Case study: Baghajatin & Kajipukur lakes

MADURAI
Mr Parmesh,
Site in-charge, site office,
Shanti Niketan Residential Enclave,
Madurai, Tamil Nadu.
Phone: 9843326583
(Regulations)
Chapter 3: Policy and Practice

N Arunachalam
Plot No 99, Justice Shire,
Shri Jaya Vilas Gardens,
Kadachenandal,
Madurai – 625 107,
Tamil Nadu.
Phone: 0452 3204711
(No municipal supply)
Chapter 11: Case study: Residence of N Arunachalam

MANGALORE
Sister Jeraldine
Somarpann Convent,
Generalate of the Ursuline Franciscan Sisters,
'Somarpann', Panir,
Derlakatte PO 574 160,
Mangalore, Karnataka.
Phone: 0824 220 2803
E-mail: jeraldineufs@rediffmail.com
(Rainwater harvesting system built-in into the system)
Chapter 12: Case study: Somarpann Convent

MUMBAI
Principal,
Jamnabai Narse School,
Juhu Narsee Monjee Bhavan,
Narsee Monjee Marg,
N.S. Road No. 7, JVPD Scheme,
Vile Parle (West),
Mumbai – 400049, Maharashtra.
Phone: 022 26187575
(Rainwater harvesting has cut down water costs)
Chapter 12: Case study: Jamnabai Narsee School

U M Paranjpe,
Jalvardhini Pratishthan,
1, Janki Niwas, Gokhale Road (North),
Dadar, Mumbai,
Maharashtra.
Phone: 9820788061
E-mail: paranjpe.ulhas@gmail.com
(Rainwater harvesting has cut down water costs)
Chapter 12: Case study: Jamnabai Narsee School

Prabodhan Krida Bhavan
Sidharth Nagar, Goregaon
Mumbai – 400 014
Phone: 022-28797582-83
E-mail: kridabhavan@prabodhan.org
(Reduction of water use from munciapl supply and recharge of aquifer)
Chapter 14: Case study: Recreational places (Prabodhan Krida Bhavan, Mumbai)

Sandeep Adhyapak,
Water Field Technologies,
C-16, Golden Willows,
Vasant Gardens, Near Swapna Nagari,
Mulund (W), Mumbai – 400 080.
E-mail: waterfieldindia@gmail.com
Phones: 022 21643331, 9821340043
(Reduction of water use from munciapl supply and recharge of aquifer)
Chapter 14: Case study: Recreational places (Prabodhan Krida Bhavan, Mumbai)

MUSSOORIE
Harshada P Worah,
Hotel Padmini Nivas,
The Mall, Mussoorie – 248 179.
Uttarakhand.
Phone: 0135-2631093/2630092
Chapter 6: Storage

Stephen Alter,
Oakville,
Mussoorie – 248 179,
Uttarakhand.
E-mail: StephenAlter@woodstock.ac.in
(Supplements municipal supply)
Chapter 11: Case study: Residence of Stephen Alter

MYSORE
H Ramesha,
No 3, Bank Colony, Bogadi,
Mysore – 570 026,
Karnataka.
Phone: 9481169733
E-mail: hebbale@gmail.com
(Drinking water, individual house)
Chpater 11: Case study: Drinking water

NEW DELHI
Vandana Menon,
2, Nizamuddin East,
New Delhi – 110 013.
Phones: 0111 4350813/2305, 9811095242
(Stop waterlogging by capturing rainwater flowing in stormwater drains)
Chapter 11: Case study: Nizamuddin (East) colony

Sarvagya Srivastava,
Chief Engineer,
Parliament Civil Work Zone,
Parliament Complex,
Pandit Pant Marg, New Delhi - 110 001.
Mobile: 98107 04614
Chapter 12: Case study: Rashtrapati Bhawan

Ravindra Yadav
Chief Engineer,
Indian Spinal Injuries Centre,
Sector - C, Vasant Kunj,
New Delhi 110070
Phone: 011 42255234
E-mail: ravinderisic@yahoo.com
Chapter 12: Case study: Indian Spinal Injuries Centre

Dr
Ms Neeta Anand
C-486, Defence colony,
New Delhi,
Phone: 011 2465662
(Using stormwater drains)
Chapter 11: Case study: Defence Colony

Project Director,
Nizamuddin Urban Renewal Initiative,
The Aga Khan Development Network,
K-15 Jungpura extension,
New Delhi – 110 014.
Phone: 011 40700720, 43717792
www.nizamuddinrenewal.org
(Revival of urban water body)
Chapter 15: Case study: Nizamuddin Baoli

PUNE
Jyoti Panse,
Jyoti Panse and Associates,
820/2 Runanubandh Manas Lane,
Off Bhandarkar Institute Road,
Pune: 411 004,
Maharashtra.
Phone: 020 25672994
Chapter 4: Planning and designing

Comprehensive Water Management Solutions Pvt Ltd (CWMS),
820/2 Runanubandh Manas Lane,
Off Bhandarkar Institute Road,
Pune: 411 004
Maharashtra.
Phone: 020 25672994
Chapter 4: Planning and designing

RAJKOT
The Municipal Commissioner,
Rajkot Municipal Corporation,
Dhebarbhai Road,
Rajkot – 360 001.
Phone: 0281 2239973
E-mail: mc_rmc@rmc.gov.in
Chapter 14: Case study: Race Course, Rajkot

SHILLONG
Mr G Pariyat,
State Office,
General Administration Department,
Barik Point,
Shillong 793 001
Meghalaya.
Phone: 0364 222 2462
Chapter 11: Case study: Deputy Chief Minister's house, Shillong

SHIMLA
Indian Institute Of Advanced Study,
Rashtrapati Nivas,
Shimla – 171005
Himachal Pradesh
Phone: 0177 2830006
email: directoriias@gmail.com
(Pre-Independence, British-built, rainwater harvesting system constructed with the building)
Chapter 12: Case study: Rastrapati Nivas

Headmaster,
Bishop Cotton School,
Shimla – 171 002,
Himachal Pradesh.
Phone: 0177 2620880, 2620990,
E-mail: headmaster@bishopcotton.com
(Potable use during rainy season, non-potable uses at all other times)
Chapter 12: Case study: Bishop Cotton School

THIRUVANANTHAPURAM
Project Coordinator,
Malankara Social Service Society,
St Mary's Compound,
Pattom,
Thiruvananthapuram – 695 004,
Kerala,
Phone : 9447660420/0471 2552892
E-mail: info@msss.org
(Water for all non-potable purposes)
Chapter 12: Case study: Malankara Social Service Society

Sri Aditya Raghunath Dy manager
Sri Rangji Mandir,
Vrindavan 281121
Uttar Pradesh
Phone: 0565 2442787
(Controlling water logging)
Chapter 12: Case study: Sri Rangji Mandir

CONTACT DETAILS OF GOVERNMENT INSTITUTIONS

AHMEDABAD

Ahmedabad Urban Development Authority,
Sardar Vallabhbhai Patel Sankul, Usmanpura,
Ashram Road, Ahmedabad – 380 014,
Gujarat.
Phone – 079 27545051/54
urban@auda.org.in

BENGALURU

Public Relations Officer
Bangalore Water Supply and Sewerage Board
1st & 2nd Floor,
Cauvery Bhavan,
K G Road,
Bengaluru – 560 009.
Help desk numbers – 080 23341652, 23348848, 23348849
http://www.bwssb.org/rainwater_harvesting.html

Rainwater Harvesting Cell,
Karnataka State Council for Science and Technology,
Indian Institute of Science,
Bengaluru – 560 012.
Phones: 080 23341652, 23348848, 23348849
Website: http://kscst.org.in/rwh.html

BHOPAL

Officer-in-charge,
City Planning Department,
Building Permission Section,
Bhopal Municipal Corporation,
6 No Bus Stop, Shivaji Nagar,
Bhopal.

CHENNAI

Rainwater Harvesting Cell,
TWAD Board,
1, Kamarajar Salai,
Chennai – 600 005.

Senior Hydrogeologist,
RWH Cell/CMWSSB,
No 1, Pumping Station Road,
Chintadripet, Chennai – 600 002.
Website: chennaimetrowater.tn.nic.in

HYDERABAD

Rainwater Harvesting Cell,
Hyderabad Metropolitan Water Supply and Sewerage Board,
Khairatabad,
Hyderabad – 500 004,
Andhra Pradesh.
http://www.hyderabadwater.gov.in/wwo/UI/rainwaterharvesting.aspx

INDORE

City Engineer's Office,
Rainwater Harvesting Cell,
Indore Municipal Corporation,
Palika Plaza, MTH Compound,
Indore.

MUMBAI

Rainwater Harvesting and Water Conservation Cell,
Municipal Corporation of Greater Mumbai,
Municipal Head Office Annexe,
3rd Floor, Mahapalika Marg,
Mumbai – 400 001.
Email: aerwhbmc@yahoo.co.in
Website: msgm.gov.in/Inititaives/Rainwater harvesting

NEW DELHI

Executive Engineer (Rain Water Harvesting),
Delhi Jal Board,
Room No.11, Varunalaya Ph-I,
Near Jhandewalan Mata Mandir,
Karol Bagh, New Delhi – 110 005.
Help Desk No: 23558264 & 23678380-82 Extn 227
http://www.delhi.gov.in/wps/wcm/connect/doit_djb/DJB/Home/Rain+Water+Harvesting/

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3. In land use, a setback is the distance which a building or other structure is set back from a street or road, a river or other stream, a shore or flood plain, or any other place which needs protection. Depending on the jurisdiction, other things like fences, landscaping, septic tanks,

and various potential hazards or nuisances might be regulated. Setbacks are generally set in municipal ordinances or zoning. Setbacks along state, provincial, or federal highways may also be set in the laws of the state or province, or the federal government
4. http://www.mcgm.gov.in/irj/portalapps/com.mcgm.solidwastemanagement/docs/RWH_E2.pdf, http://www.mcgm.gov.in/irj/portalapps/com.mcgm.ecohousing/docs/RainWaterHarvesting.pdf, as viewed on March 1, 2012

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Box: Specifications for rainwater harvesting

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Box: Innovations arising from water scarcity

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1947 - 2002

"A time will come when even fancy urban citizens in megacities will be using their roofs for capturing rainwater. I say this because we are rapidly polluting all our rivers and groundwater systems with agricultural chemicals and industrial poisons."

Anil Agarwal

Founder director

Centre for Science and Environment

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
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